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CANNING TECHNOLOGY

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by

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With a Foreword by
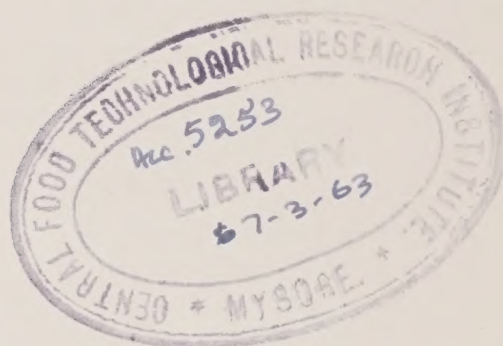SIR JACK DRUMMOND, D.Sc., F.R.S.

With 113 Illustrations

Dedicated to

The Rt. Hon. Lord Woolton, P.C., C.H., D.L.,

Minister of Food, 1940-43

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FOREWORD

It is a pleasure to contribute a foreword to Mr. Howard's book. I do not know what proportion of those who write forewords actually read every word of the book they help to introduce, but I can assure Mr. Howard, and the many readers who will enjoy this volume, that starting with a cursory glance at its pages, I was drawn by the magnetism of his clear and expert style to read it from beginning to end.

The great canning industry of the world today looks back over a history of a little more than a century, a century of brave enterprise, baffling problems, disheartening failures and brilliant achievement.

Only in comparatively recent times has the public lost its fears of canned foods, fears that in a large measure can be traced back to the catastrophic events that shattered the foundations of the industry in its very early days.

Today, scientific study having achieved so much, canned products are accepted everywhere as good, nutritious, safe and palatable foods. If any proof were called for, innumerable examples could be drawn from the experience of the war years.

Mr. Howard has put us in his debt by bringing together in so clear and ordered a manner the whole story of canning, from beginning to end. His own wide experience in the industry enables him to present the picture in admirable perspective and with commendable clarity.

J. C. Drummond.

PREFACE

THE production of canned foods has now become a major industry in many countries throughout the world. It is not surprising, therefore, that every aspect of the industry has been the subject of exhaustive scientific investigation, and that whereas fifty years ago little was known of the fundamental principles underlying the canning process there is today a voluminous and ever expanding literature on the subject scattered throughout the scientific and technical journals of the world. The present volume is written, therefore, not merely as a description of the methods of the industry, but also to provide the reader with an account of the fundamental considerations upon which modern canning technology is based. With this in mind frequent references are made to the scientific literature throughout the text. Although this book is primarily written for the canner and cannery operative, it is hoped that the inclusion of the sections on tinplate and can manufacture will make the book of service to the producers of these important ancillary materials, while the frequent references to the literature should be of value to the student and the research worker.

In the preparation of this book I am indebted to many people for assistance and advice, but especially to Dr. C. G. Sumner for reading much of the manuscript, for revising that part of Chapter 3 dealing with the electrochemical theory of corrosion, for providing the first connected account to be published of the work he and his colleagues carried out under the direction of Dr. W. Clayton which led to the development of the electrochemical processes for the prevention of the corrosion of tinplate, and finally for Figs. 21 and 22.

My best thanks are also due to the following : Dr. E. S. Hedges and Mr. W. E. Hoare for permission to use material from their book "Tinplate," and to Messrs. Edward Arnold and Co. for the loan of blocks from the same work ; Mr. F. Hirst for permission to reproduce material from the annual reports of the Fruit and Vegetable Preservation Research Station, Campden, and for the use of other published material ; The Tin Research Institute for Figs. 23, 24, and 28 ; Mr. R. I. Johnson, Director of Canning, Ministry of Food, for assistance in the early stages of the preparation of the manuscript ; The Director of the National Canners' Association, U.S.A., for permission to reproduce Figs. 26 and 66 ; Dr. D. Nickelsen of A/S Nordisk Aluminiumindustri, Norway, for information on the use of aluminium for can making, and for Figs. 108 and 109 ; Mr. J. G. Baumgartner of Messrs. Crosse and Blackwell Ltd. for Figs. 71 and 88, and also for advice and assistance ; Messrs. T. E. Bashford, F. C. Lewis, and R. Taggart of The Metal Box Co. Ltd., for reprints and permission to reproduce diagrams and graphs ; The Controller, H.M. Stationery Office for permission to reproduce Fig. 25. Many scientific and technical journals, trade papers, bulletins, articles and reports have been consulted in the preparation of this volume and my gratitude and appreciation are extended to the authors and editors from whom I have received permission to use material the source of which is acknowledged in the text and references.

Various manufacturers of canning equipment, tinplate, cans, and other ancillary materials have contributed photographs and advice which has been of invaluable assistance in preparing this volume, and due acknowledgement is made in the text at the point of insertion of the material.

I am deeply conscious of the honour conferred on this book by the inclusion of a Foreword by Sir Jack Drummond, and I offer him my sincere thanks.

Finally, I should like to express my appreciation of the care and attention which my publishers have devoted to the preparation of this volume.

Belfast.

A. J. HOWARD.

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CHAPTER 1

HISTORICAL INTRODUCTION

The Development of the Canning Industry

THE preservation of food was practised before the beginning of recorded history and some of the methods adopted by the ancients are still in use in a modified form at the present time. Drying, for example, by the aid of heat from the sun was probably one of the first methods to be adopted, while salting and pickling were introduced at an early date.

Approximately one hundred years before the work of Louis Pasteur demonstrated that the causative organisms of food spoilage, and certain diseases, were airborne, a keen controversy raged over the theory of "spontaneous generation," the protagonists of which believed that life was developed spontaneously in organic matter. Needham[1], for example, boiled mutton gravy then enclosed it in a vessel which was tightly corked, and a few days later found that the gravy was filled with small organisms, whereupon he concluded that they had developed spontaneously in the infusion of organic material.

It was not long after the publication of Needham's work that his results were challenged by a well-known Italian naturalist named Spallanzani[2], who carried out careful experiments from which he concluded that organisms causing spoilage in a number of food products were carried in the air, and that by heating the contaminated infusions in airtight vessels the development of the organisms was prevented. These conclusions were far ahead of their time and were very much the same as those reached by Pasteur[3] some hundred years later.

Although Spallanzani's work was the key to the preservation of food by heat, little use appears to have been made of it until the early part of the nineteenth century when Nicholas Appert first succeeded in preserving food in airtight glass containers.

The canning industry was conceived in a time of war when the French Government was in great difficulty in supplying Napoleon's Army and the Navy with food, so much so, that in 1795 a prize of 12,000 francs was offered for a means of preserving food for long periods. The prize was eventually won by Appert, who received his early training as a confectioner and was a keen experimenter and an accurate observer. He began his studies on food preservation in

1795 and in 1804 had succeeded in preserving food in glass containers, finally being awarded the prize in 1809. His first treatise on food preservation was published in 1810[4], the English translation entitled "The Art of Preserving All Kinds of Animal and Vegetable Substances for Several Years" appearing the following year.

It is unlikely that Appert was aware of the work of Spallanzani and his work is, therefore, all the more remarkable as it was not until nearly half a century later following the work of Pasteur[3] that the real causes of food spoilage were generally recognised.

In his book Appert described the four important steps in his method as follows :— "(1)   In enclosing in bottles the substance to be preserved : (2) in corking the bottles with the utmost care, for it is chiefly on the corking that the success of the process depends ; (3) in submitting the enclosed substances to the action of boiling water in a water bath, for a greater or less length of time, according to their nature, and in the manner pointed out with respect to each of several kinds of substance ; (4) in withdrawing the bottles from the water bath at the end of the prescribed period."

From the above it will be seen that Appert enunciated all the principles which, with added refinements, operate in every cannery to the present day.

It was not long before the methods originated by Appert found their way to America and in 1819 an Englishman named William Underwood was packing food in glass jars in Boston, while in the same year another Englishman, Thomas Kensett, was using similar methods to preserve food in New York. Kensett, according to May[5], admitted his father-in-law Ezra Daggett into the business in 1819.

Although Appert originally used a water bath for sterilising his glass jars efforts were soon made to increase the temperature of the bath by adding such substances as common salt or calcium chloride and thus shorten the time required for sterilisation. Patents on this subject were granted to Fastier[6] in France in 1839, and to Goldner[7] and Wertheimer[8] in England in 1841.

The first attempt to use pressure for the cooking of food was, according to Bitting[9], made by Papin in 1681, but the first use of steam or water under pressure for sterilising canned foods is somewhat obscure, the name of Winslow in 1843, and of Raymond Chevalier-Appert being mentioned by May[5]. These early pressure vessels were liable to frequent explosions as also was the process of heating the cans in baths containing dissolved chemicals.

The employment of an autoclave, which received its steam from an outside source, is attributed by Orem[10] to Shriver in 1874. The use of a pressure vessel for sterilising canned foods represented a great advance in canning technique as it not only reduced the length of

time required to sterilise the can and its contents, but it also permitted the packing of a wider range of foods than had hitherto been possible.

It is of interest to note that the modern tendency is to shorter processing times at higher temperatures in an attempt to improve the quality of the product. An interesting account of the progress made in the processing of canned foods has been given by Ball[11], and the reader is referred to this review for a detailed list of the various methods adopted for processing.

The Development of the Open Top or Sanitary Type of Can

Shortly after Appert had been awarded the prize for his method of food preservation a patent was granted to Augustus de Heine[12] for the use of iron containers for preserving food, while in the same year, 1810, Peter Durand[13] was granted a similar patent covering the use of tinplate containers and also a method of preserving food which appears to have been based on Appert's work, and is the first English patent on canning. The establishment of Donkin and Hall's canning factory at about the same time is mentioned by Drummond and Lewis[14], and it is interesting to note, in view of the modern method of incubation, that it was customary to test the finished cans by placing them for a month or more in a closed chamber heated to a temperature of 90°–110°F., any defective cans being detected by the bulging of the ends.

The "tinplate canister," as it was then called, the name being later shortened to "tin cans" or "tins" in England and "cans" in America, was extremely crude in construction compared with the modern can.

These early cans were made entirely by hand, the tin coating was extremely heavy, a figure of over 8lb. per basis box being obtained by Lewis[15] in the examination of some cans of this period.

The blanks for the bodies and ends were cut out by hand shears, the body blanks were bent round a roller, the overlapping edges being soldered together to form the side seam. The discs for the ends were cut slightly larger than the diameter of the body and the overlapping edges were turned over forming a flange which fitted tightly over the body in a somewhat similar manner to that of the present day fully-soldered venthole milk can. The flanging of the ends was done by hammering the disc of tinplate over a stake. A hole was cut in one of the ends for filling, the hole then being closed by soldering on a small disc of tinplate.

These hole-and-cap cans as they were called were used very early n the history of canning. A patent granted to Fastier[6] in 1839

discloses the use of a can of this type, but they were used by Gamble as early as 1824.

In an attempt to make possible the re-use of containers Angilbert[16] patented a can in which the full aperture could be used for filling, and thus came near to the type of can used at the present time, but the method of closing he used was somewhat cumbersome, although he did describe the use of a venthole to permit the escape of gases generated during the first stage of sterilising, and this was afterwards adopted for the ordinary type of can.

Cans continued to be made mostly by hand until 1847 when the drop press was invented in America. This machine produced flanged ends from flat discs by dropping a heavy die on to the blank.

Shortly afterwards the pendulum press was invented, to be quickly followed by the combination press which cut the discs from the flat sheet, flanged them and at the same time punched the filler holes.

This increase in production of ends resulted in a demand for the more rapid production of bodies, and various mechanical aids were invented to assist the tinsmith. In 1858 a method for soldering on the ends was invented in which the body with the end in position was rotated in a solder bath while being held in an inclined position so that only the end seam dipped below the surface of the molten solder. This method increased the daily output from 60 cans per man to 1,000 and also reduced the amount of solder used by nearly one half.

Shortly after machines were developed for soldering the side seams, and in 1876 the solder float was brought out by Howe[17], by which means the end seams were soldered by rolling the cans, inclined at an angle, through a bath of solder in a manner analogous to that at present used for the manufacture of the fully soldered venthole milk can.

At about this time great attention was being paid to the development of easy opening cans as this was a matter of some difficulty, the instruction "to cut round the can end with a hammer and chisel" being a common inscription on the label.

An excellent description of the early attempts at making cans of this type is given in a bulletin[18] published by the International Tin Research and Development Council, from which a great deal of the subject matter for this Chapter is abstracted.

For many years the filler hole can remained the standard type for a wide range of products, but the size of the hole in the end made the washing of the interior of the can an uncertain and difficult process and, furthermore, it limited the size of the objects with which the can could be filled and also tended to damage the larger products which had to be forced through the relatively small filler hole.

The advantages of the "open top" type of can where the full diameter of the body could be used for filling were obvious and a

description of the many types of this can which were developed is given in the bulletin already referred to above.

The application of the locked side seam to the manufacture of food cans dates back to about 1861 when Peltier[19] obtained a patent for a machine to make a can of this type.

The introduction of the double seam for joining ends to bodies is somewhat obscure, but it is stated in the above bulletin that the catalogue of Messrs. Joseph Rhodes of Wakefield lists machines for the production of this type of seam as far back as 1824, and that rubber was suggested as a seal in the recesses of the ends when liquids and semi-solids were packed.

Although the patent literature towards the end of the nineteenth century on the subject of food cans is extensive it was not until 1900 that the Ams brothers[20] produced the prototype of the present day "open top" or "sanitary" can as it is sometimes called. The secret of their success was the type of compound used for lining the can ends to produce a hermetic seal and overcome the effects of the discontinuities resulting from variation in the thickness of the tinplate and wear on the seaming rolls.

The full mechanisation of the process of can making quickly followed and has now reached a stage where fully automatic machines are capable of turning out up to 350 cans per minute with the number of defective cans rarely exceeding 0.2 per cent.

The lacquering of cans to minimise the effects of corrosion has been traced back to 1868 when Peltier and Paillard[21] of Paris used a varnish for this purpose, while in 1882 Parry and Cobley[22] proposed to coat cans with sodium or potassium silicates, calcium silicate and a serum made of various protein containing materials.

A detailed description of the types of lacquers and the methods used for lacquering the modern open top can will be found in Chapter 4.

The Application of Bacteriology to Canning Technique

The science of bacteriology, as we now know it, commenced with the observations of Anthony van Leeuwenhook in 1675. A very interesting and complete study of the life of this pioneer of bacteriology has been made by Dobell[23], and the reader is referred to this work for a detailed description which is beyond the scope of this volume.

As stated earlier in this Chapter it was for a long time thought that micro-organisms were generated spontaneously and it was not until Pasteur[3] finally exploded this idea that the way for the new science of bacteriology was open.

The early canners had little knowledge of bacteriology, and probably less regard for it, and their sterilisation methods were mainly arrived

at by trial and error, and losses due to spoilage were often
heavy.

It was appreciated that the exclusion of air was necessary for the
preservation of foods, but it was not realised that the air carried
living organisms and, consequently, a theory developed that the air
per se was the causative factor in food spoilage. Great emphasis,
therefore, was placed on the importance of obtaining a high vacuum
in the finished can, and it is only in recent years that the association
of a good vacuum with sterility has been discarded.

The first recorded investigation of a case of bacteriological spoilage
in canned food was made by Russell[24] when he was called in by a
canner in Wisconsin in order to trace the cause of a sudden increase
in the number of blown cans of peas. By inoculating sound cans with
cultures from the defective cans and examining cultures of the latter
under the microscope Russell was able to show that the blown cans
contained gas-producing organisms which had not been destroyed
by the sterilising process. He demonstrated that by increasing the
temperature and time of the process the number of defective cans
could be reduced to negligible proportions.

Two years after Russell had carried out his work on the spoilage
of canned peas Prescott and Underwood[25] described their experiments
in inoculating canned foods with various spoilage organisms and
they concluded that certain organisms were more resistant to heat
than others and that temperatures in excess of those obtained with
the open water bath were necessary if the processing time was to
be kept within reasonable limits.

Further work by the same authors[26] included the use of small
registering thermometers which were placed in the can before sealing
and recorded the highest temperature reached during processing.
This second paper referred particularly to the processing of sweet corn.

The arbitrary and rule-of-thumb determination of processing times
and temperatures adopted by the early canners has now been replaced
by precise methods which take into account the rate of heat pene-
tration through the filled can and the thermal death times of the
organisms it is desired to destroy.

In the foregoing brief history of the development of the canning
industry it has not been possible to cover all aspects of an intensely
interesting subject, but sufficient has been said to enable the reader to
appreciate the many difficulties which beset the pioneers of the
industry.

To-day the food can is ubiquitous and little thought is given to the
many branches of science which have played their part in bringing
canning technology to the high state of perfection it has now reached.

It behoves every canner to maintain the high reputation that

canned foods have gained throughout the world by setting a high standard of quality and ensuring that this standard is at all times maintained.

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CHAPTER 2

THE MANUFACTURE OF TINPLATE

ONE of the most important raw materials used by the canner is tinplate, and although cans now being supplied by can fabricators reach a very high standard of perfection it still behoves the canner to examine incoming cans, in common with all other raw materials, to ensure that there are no unforseen deviations from specified standards.

It is with this thought in mind that the present chapter is written, and although it is not suggested that the canner should maintain a full scale metallurgical laboratory, it is suggested that he should be familiar with the methods of manufacture of tinplate and the essential properties which are necessary to ensure a satisfactory can and a normal shelf life for the finished product.

The manufacture of tinplate can be traced to the early Middle Ages, and it is reported[1] that a Cornish tin miner fleeing from his native land discovered tin in the mountains of Bohemia and there established a tinplate industry. As already stated in Chapter 1, the use of tinplate for the manufacture of food containers was patented by an Englishman, Peter Durand[2], who thus laid the foundations for what is now a great industry, although it was not until some years later that metal containers came into general use.

In the early days of the tinplate industry iron sheets were beaten out by hand until they reached the desired thickness, but it was not long before the advent of the rolling mill superseded manual labour, and modern tinplate is now made either by the older and rapidly disappearing pack rolling process or by the more modern continuous strip method.

An interesting chronological survey of the development of the British tinplate industry has been made by Brooke[3].

The manufacture of tinplate begins with the production of suitable steel ingots, which for use in the pack rolling process may weigh from one to two tons, while those used for continuous strip rolling may weigh up to seven or eight tons.

It is not within the scope of this volume to describe the manufacture of steel in detail, and the reader is referred to the many well known and extensive works on the subject for further information.

The composition of the steel is an important factor in determining the corrosion resistance of the tinplate and is more fully discussed in Chapter 3, but it should be noted that it is necessary in the pack rolling process to have a high phosphorus content in order to reduce the tendency of the sheets to adhere to one another. This phosphorus content is a disadvantage as it decreases the corrosion resistance of the tinplate, and is one of the primary reasons why the pack rolling process is being superseded by the continuous strip process, as with this method of rolling it is possible to use steels with very low phosphorus content and thereby increase the corrosion resistance of the finished tinplate.

Pack Rolling

This process, which was largely developed in South Wales and is, therefore, sometimes known as the Welsh process, was the method on which the tinplate industry was founded. The five main operations involved have been summarised by Hoare and Hedges[4] as follows :—

(1) Bar cutting, where the tinplate bars are cut to lengths equal to the required width of the finished tinplate.

(2) Reheating, where the tinplate bars from the previous operation are brought up to the right temperature for rolling.

(3) Rolling, conducted in stages, each stage being preceded by reheating.

(4) Doubling, where the sheet or pack is folded in halves and the fold is closed tight by means of a vice.

(5) Shearing, which occurs at two main points: in the trimming of the ends of the doubled packs to keep one end free ; and in the shearing to size of the finished pack of eight sheets.

Although on the face of it the reheating of the cut bars is a simple enough process, it plays a great part in the quality of the finished product and considerable work has been carried out to increase the efficiency of this operation. Modern reheating furnaces are of the continuous type, providing a more even heating and closer control of the atmosphere in which the bars are heated than was formerly possible.

After reheating, the bars are plunged into a tank of water, an operation known as "boshing," the object being to assist in the removal of the scale developed during reheating. After boshing comes the rolling process, which may be carried out in a number of

different ways, but the general principles are illustrated diagrammatically in Fig. 1, although the actual routing of the packs through the rolls differs from mill to mill.

After the rolling process the packs are doubled and sheared, and then re-rolled until the desired reduction in thickness is attained, by which time a pack of sheets has been formed.

The doubled packs must now be opened, and this is accomplished manually or by means of automatic machines.
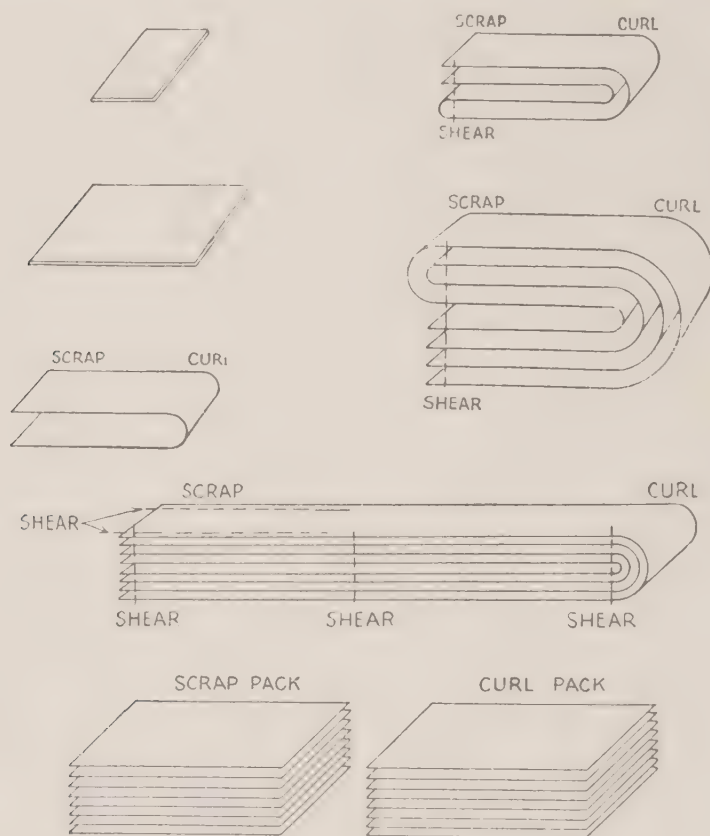
Fig. 1. Steps in pack rolling (five part system). The original bar is rolled, reheated, rolled and doubled until sixteens sheets are ultimately obtained.

(*Hoare and Hedges : "Tinplate"*)

As a result of the reheating during the rolling process the sheets are covered in a thin film of oxide, in fact if this were not so the sheets would stick together and it would be extremely difficult to separate the rolled pack. This oxide film must be removed before the sheets are annealed, and this is carried out by pickling in dilute acid, usually sulphuric of about 8 per cent strength. During the pickling process there will be some dissolution of the metal, which must be kept at as low a value as possible, otherwise the consumption

of acid and loss of metal will reach an uneconomic level. To minimise the action of the acid, "inhibitors" are added to the pickling solution, and a great deal of research work has been carried out on the development of effective inhibitors which will reduce the rate of attack on the metal without greatly curtailing the rate of removal of the oxide film.

Many substances have been suggested from time to time for use as inhibitors; Friend and Vallance,[5] for example, investigated the effect from the colloid angle, while reference is made to other work in Chapter 3.

In the pack rolling process batch type pickling baths are used, the sheets being placed in racks and successively dipped in acid and washing baths. There are two distinct pickling operations: the first which follows hot rolling is called *black pickling*, and the second which follows the final annealing process is called *white pickling*.

After black pickling annealing takes place and in the pack rolling process this is termed *black annealing* the object being to produce sheets with the correct physical characteristics and grain structure for the subsequent fabrication of the can. In this operation the wet sheets from black pickling are piled on beds, covered with steel covers, and heated to a temperature slightly below the critical point of the metal, usually about 750—850°C., and then allowed to cool slowly, the heat being supplied by gas burners or other means.

After black annealing the sheets are cold rolled with the object of increasing the smoothness of the surface of the sheet and thus facilitating the tinning operation. In cold rolling cleanliness is of the utmost importance, as any dirt or grease falling on the sheet may give rise to defects in tinning, and for this reason the surface of the rolls must be maintained in a highly polished condition, otherwise marking of the sheets will occur.

Cold rolling increases the hardness of the sheet and this is removed by *white annealing*, a similar process to black annealing but carried out at a lower temperature. After this process the sheets are ready for white pickling and the tinning processes discussed later in this Chapter.

Continuous Strip-Rolling

The introduction of the continuous strip-rolling process for the manufacture of tinplate base has altered the whole structure of the tinplate industry, and it will not be long before the greater part of the world's tinplate is made by the new method.

As its name implies, continuous rolling of strip for tinplate involves the production of a long strip of steel, as opposed to the series of small sheets produced by the pack rolling process. This radical change in

procedure necessitated the adoption of methods for the handling of long strips of steel and has resulted in a complete revision of the lay-out of the tinplate mill.

It is appropriate at this point to consider the properties of cold-reduced steel strip and sheet, which have led to the almost complete eclipse of the old established pack-rolled plate in the U.S.A. and to a lesser, but ever increasing extent in the United Kingdom and other tinplate-producing countries.

Many difficulties had to be overcome before cold-reduced plate reached the high standard obtaining at the present time, and its adoption by can makers only took place after it had been convincingly demonstrated that it possessed several advantages. Comparison of the properties of the two types of tinplate has been made by Stobbs[6], of which the following are the most important :—

  (1) Improved mechanical properties.
  (2) Improved resistance to corrosion.
  (3) Less variation in sheet dimensions.
  (4) Improved tin coatings.
  (5) Better appearance.

As far as mechanical properties are concerned, cold-reduced tinplate gives better results with all the normal mechanical tests : in tests on bending machines, for example, it has been shown that cold-reduced tinplate tends to be less directional in character than is the case with pack-rolled plate. The improved mechanical properties appear to result from the closer grain structure and the fact that the grains are orientated in a more random manner than is the case with pack-rolled plate. A comparison of the micro-structure is shown in Fig. 2.

In the manufacture of steel for cold-reduced plate it has been found possible to reduce the metalloid content to a very low value, and this has not only resulted in a greater resistance to corrosion but also in improved ductility. With pack-rolled plate, as already stated, it has always been necessary to include a certain proportion of phos-phorus to prevent the sheets in the pack from sticking together.

The process of cold reduction permits a greater degree of control to be maintained over the dimensions of the final sheet or strip and cold-reduced plate can now be supplied to much finer limits than has hitherto been possible by the pack-rolling process.

The surface of cold-reduced tinplate is superior to that of the pack-rolled product, and results in a smoother and more uniform tin coating and greater freedom from defects.

It is of interest to compare the relative outputs of tinplate by the cold-reduced and pack-rolled methods. In 1936 only 23 per cent of the total tinplate produced in the U.S.A. was produced by the cold

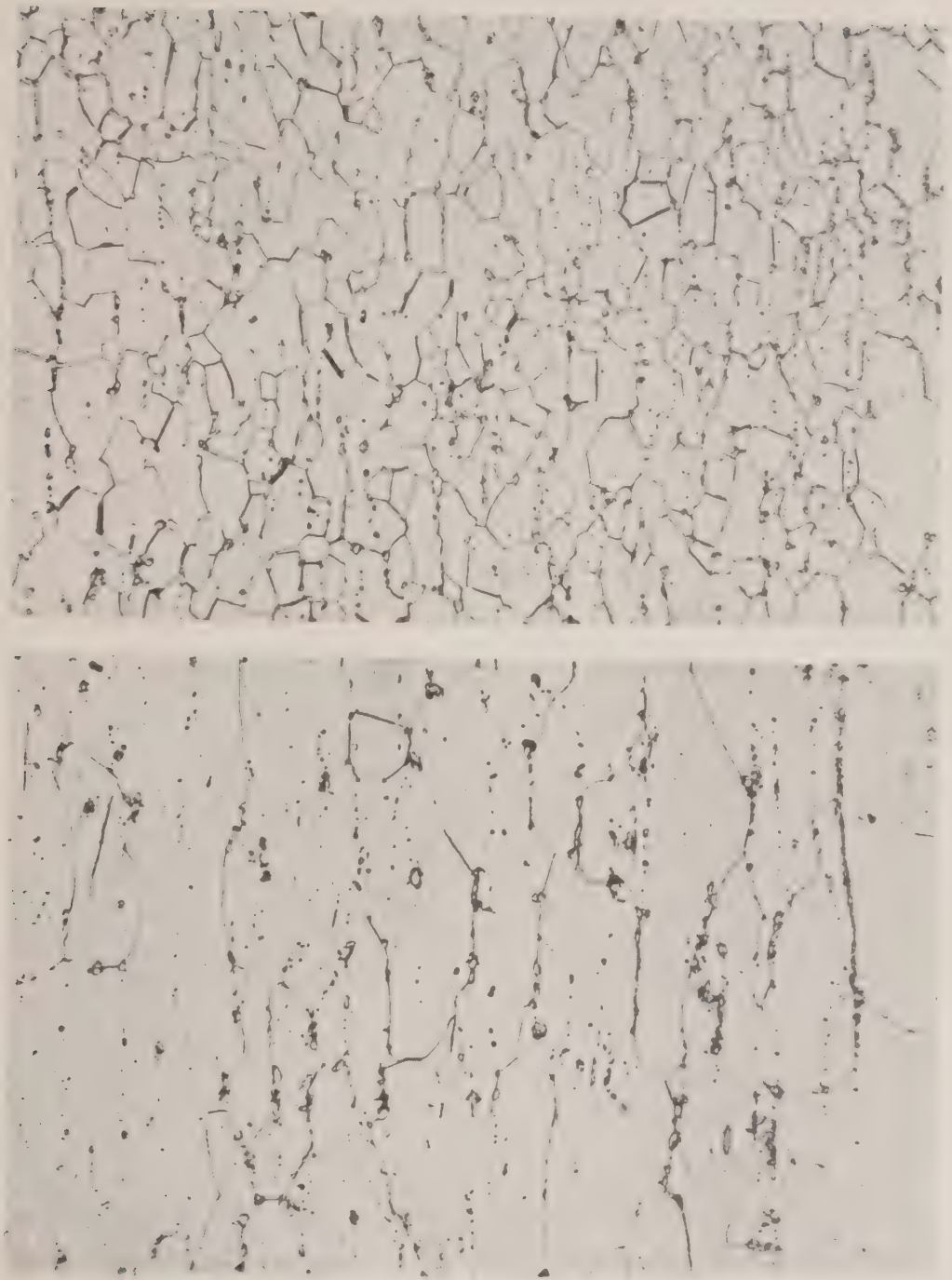Fig. 2.   Photomicrographs of etched steel sheets showing the different grain structure of (above) cold-reduced and (below) hot-rolled steel.
(*Courtesy American Can Co.*)

reduction method, but this figure rose to 75 per cent in 1939 and to 88 per cent in 1942, and it is significant that new mills being erected are all of the cold reduction type.

Equipment for cold reduction is, however, so expensive that

manufacturers have often tended to prefer the modernisation of existing pack-rolling plants rather than incur the expenditure required for a cold reduction mill, but there is little doubt that the pack-rolling process will soon cease to exist except to provide a limited supply of tinplate for special purposes, where the quantity required is so small that it could not be economically dealt with on a strip mill.

The various stages in the production of steel strip by the continuous cold reduction process may be summarised as follows :—

(1) Production of tinplate slabs in the slabbing mill.
(2) Hot rolling of the slabs down to a thickness of about 15–19 gauge.
(3) Continuous pickling of the hot rolled strip.
(4) Reduction of the hot rolled strip to tinplate thickness by cold rolling.
(5) Electrolytic cleaning of the reduced strip.
(6) Annealing.
(7) Temper-rolling.

As already stated, the continuous rolling process uses a much larger ingot than is customary in pack rolling. From this ingot, slabs about 4 to 5 inches thick and of width appropriate to the final width of the finished tinplate are rolled in a slabbing mill : these slabs may be as much as twenty feet long.

The slabs are either sent straight to the first stand of the hot mill or they may be stored until required, in which case they must be reheated in a slab-reheating furnace, where the temperature and atmosphere are carefully regulated to ensure even heating and control the amount of scale formed on the surface of the slab.

From the time the slab enters the first stand of the hot rolls no additional heating is required, any further heat being supplied by the work done in the reduction of the thickness of the slab.

Although the actual arrangement of the roughing and finishing stands varies from mill to mill the basic principles are the same. The first stand of the roughing mill is usually used for scale breaking, the object being to remove the scale produced during the heating of the slab. This operation must be carried out with great care, otherwise there will be a loss in quality of the finished sheet. The scale is broken by effecting a comparatively small reduction in thickness of the slab and then spraying with high pressure jets of water, thereby causing the scale to be blown off the surface of the steel. Following scale breaking are a number of roughing stands where the reduction in thickness of the slab commences ; these vary in number depending on the amount of reduction which takes place in each. Interposed

Fig. 3. View of hot strip mill showing strip leaving the first pair of roughing rolls.

Fig. 4. View of hot strip mill showing the finishing stands. The strip leaves the last finishing stand at a maximum speed of 1,850 feet per minute.
(*Courtesy Richard Thomas and Baldwins Ltd.*)

between the roughing stands are edgers with vertical rollers which are used to control the width of the strip. Figs. 3 and 4 illustrate a typical modern hot-strip mill.

At the end of the roughing stands follow the finishing stands where the final reduction in thickness of the strip takes place. As reduction proceeds the speed of the strip through the rollers gradually increases, ultimately reaching the high speeds shown in Table I.

TABLE I

Details of Hot Strip Mill

[Richard Thomas & Baldwins Ltd., Ebbw Vale Plant]

(*Hoare and Hedges : "Tinplate"*)

Stage	Type of Stand	Speed f.p.m.
Shear	—	250
Scale breaker	2-high	600
Squeezer	—	700
Roughing	1st 2-high	2500
	2nd 2-high	2500
	Vertical edger	200
	3rd 2-high	2500
	4th 4-high	2500
	Vertical edger	200
Scale breaker	2-high	400
Finishing	1st 4-high	3370
	2nd 4-high	3370
	3rd 4-high	3370
	4th 4-high	3370
	5th 4-high	2850

After passing through the last stand of the finishing section the strip passes on to the runout table Fig. 5. where it remains until it has reached the right temperature for coiling. The control of temperature at this point is an important factor in determining the micro-crystalline structure of the hot rolled strip and the relative ease with which coiling can be effected.

Hoare and Hedges[4] have quoted the following measurements as being characteristic of the production of continuous hot rolling mills:— A $4\frac{1}{2}$ in. thick slab, 5 ft. long, will yield about 320 ft. of 15 gauge strip, but much longer lengths may be rolled if desired.

Fig. 6 shows a coil of hot rolled strip being ejected from the coiler.

As in the pack-rolling process, a pickling operation follows hot-rolling and with a continuous strip it has been necessary to develop continuous pickling methods.

FIG. 5. View of strip passing along runout table and entering coiler.

FIG. 6. Ejection of coiled strip from coiler.
(*Courtesy Richard Thomas and Baldwins Ltd.*)

The continuous pickling line includes a processing unit, pickling, washing and delivery units, and is illustrated in Fig. 7.

The processing unit consists of equipment for uncoiling and breaking the scale from the strip, a shear for trimming the trailing edge of one strip and the leading edge of the next strip and a welder

FIG. 7. Exit end of continuous pickling unit.
(*Courtesy Richard Thomas and Baldwins Ltd.*)

or stitcher for joining the ends of the two strips together thereby ensuring continuity of operation. Finally, there is what is known as a looping pit, where a quantity of slack is allowed to accumulate so that the trailing edge of the strip may be stopped to allow the leading edge of the next strip to be joined by the welder or stitcher without stopping the whole line.

The pickling tanks vary considerably in size, although Hoare and Hedges[4] have stated that a length of approximately 60 ft. may be regarded as standard and that the number of tanks may vary from three to six, depending on the speed of the line, the amount of scale to be removed, and the operating conditions of the pickling bath. Following the pickling bath is the washing unit, which usually consists of two tanks of similar dimensions to those used for pickling, the first containing cold water, and the second hot water to assist in drying the pickled and washed strip.

The delivery unit removes the welds, oils the surface and coils the strip ready for delivery to the cold reduction mills.

The demand for still higher strip speeds has led to the development of electrolytic pickling methods in which the strip is passed between upper and lower electrodes, through which an alternating current is passed. This process has been very fully described by Neblett[7].

The efficiency of pickling has a very considerable bearing on the ultimate quality of the finished tinplate, any patches of scale which are not removed will result in discontinuities in the tin coating, while over-pickling, on the other hand, will lead to excessive consumption of the steel strip and wastage of acid.

The next process is cold reduction, in which the pickled strip is given a further rolling process to reduce it to tinplate thickness.

Cold reduction depends upon the joint effects of roll pressure and tension between the strands of rolls to produce the necessary reduction in thickness.

There are several types of mill used for this process, but the one in most general use is known as the multi-stand tandem mill, and as in the continuous hot rolling process there are many variations in the layout of a mill of this type but the general principles are shown diagrammatically in Fig. 8. The mills are driven electrically, and as
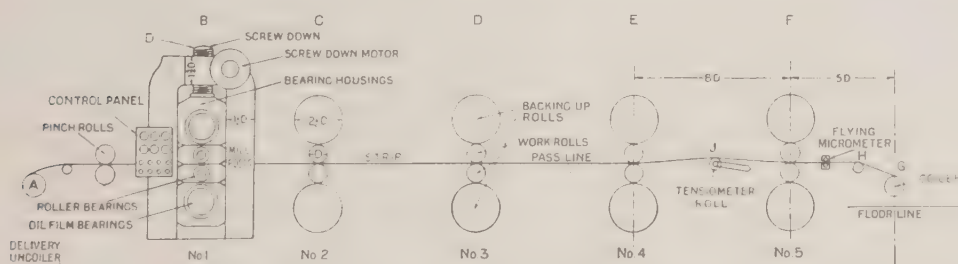
FIG. 8. Schematic diagram of multi-stand tandem cold rolling mill.
(*Hoare and Hedges : " Tinplate"*)

the strip is in all the stands simultaneously the accurate control of roll speeds and tension is of primary importance. The flying micrometer and tensiometer serve to indicate the thickness and tension of

the strip respectively, and individual adjustments of the roll speeds can be made as rolling proceeds. Figs. 9 and 10 show typical views of a modern cold reduction mill.

It is of interest to note that there has been a steady increase in the speed of rolling, and speeds of between 2,000 and 3,000 ft. per minute are now possible, while up to 4,000 ft. per minute is contemplated for the new plant to be erected in South Wales.
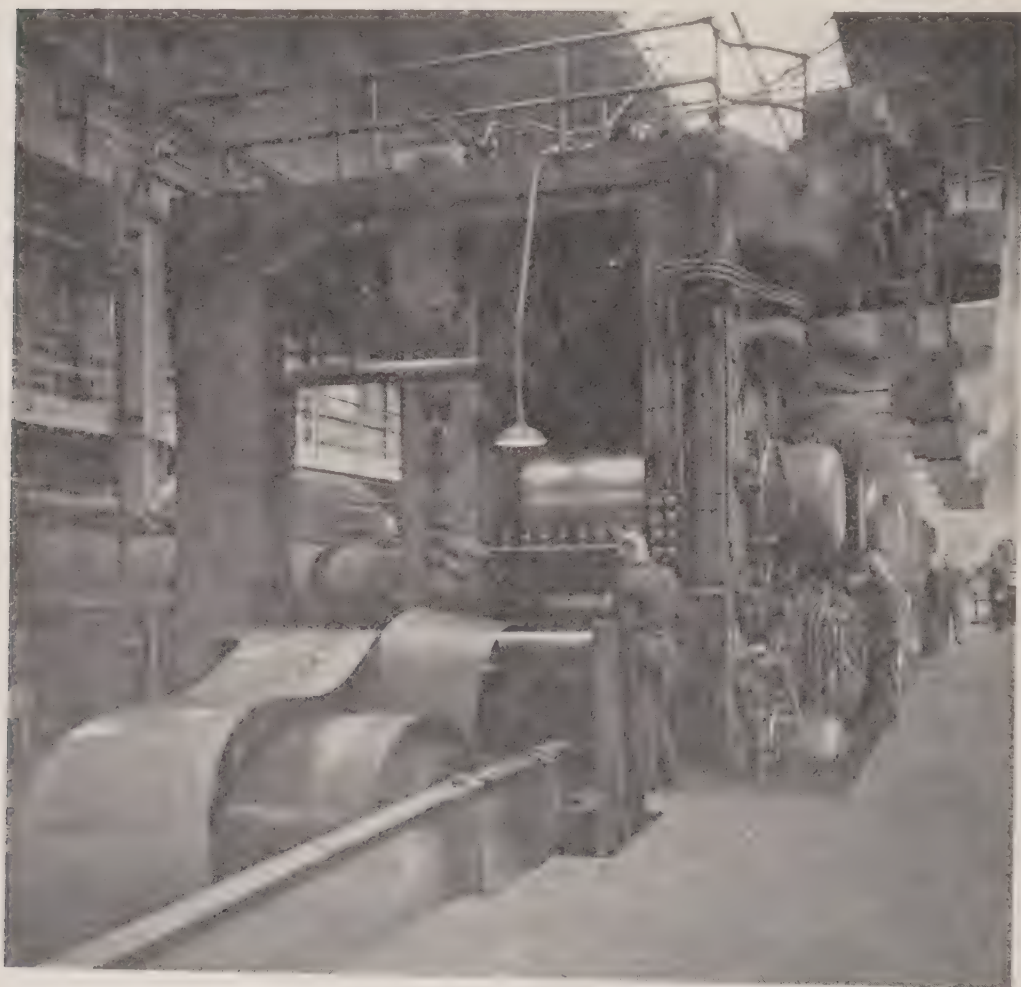
FIG. 9. Typical five stand tandem cold reduction mill at point of entry of strip.
(*Courtesy Richard Thomas and Baldwins Ltd.*)

During continuous cold rolling it is necessary to use lubricants and coolants, and these must be completely removed before annealing, otherwise the residues will bake on the surface of the strip and cause difficulty in the final pickling operation which precedes tinning. The removal of these residues is accomplished by electrolytic cleaning, the strip being first passed through a hot alkaline bath where the bulk of the oil is removed, after which the strip is made the cathode

component of an electrolytic cell to remove the remaining oil residues, and is then washed and dried.

In the cold reduction process there is only one annealing operation, and it is carried out following electrolytic cleaning by a batch process while the strip remains in coil form. The bath type annealing ovens
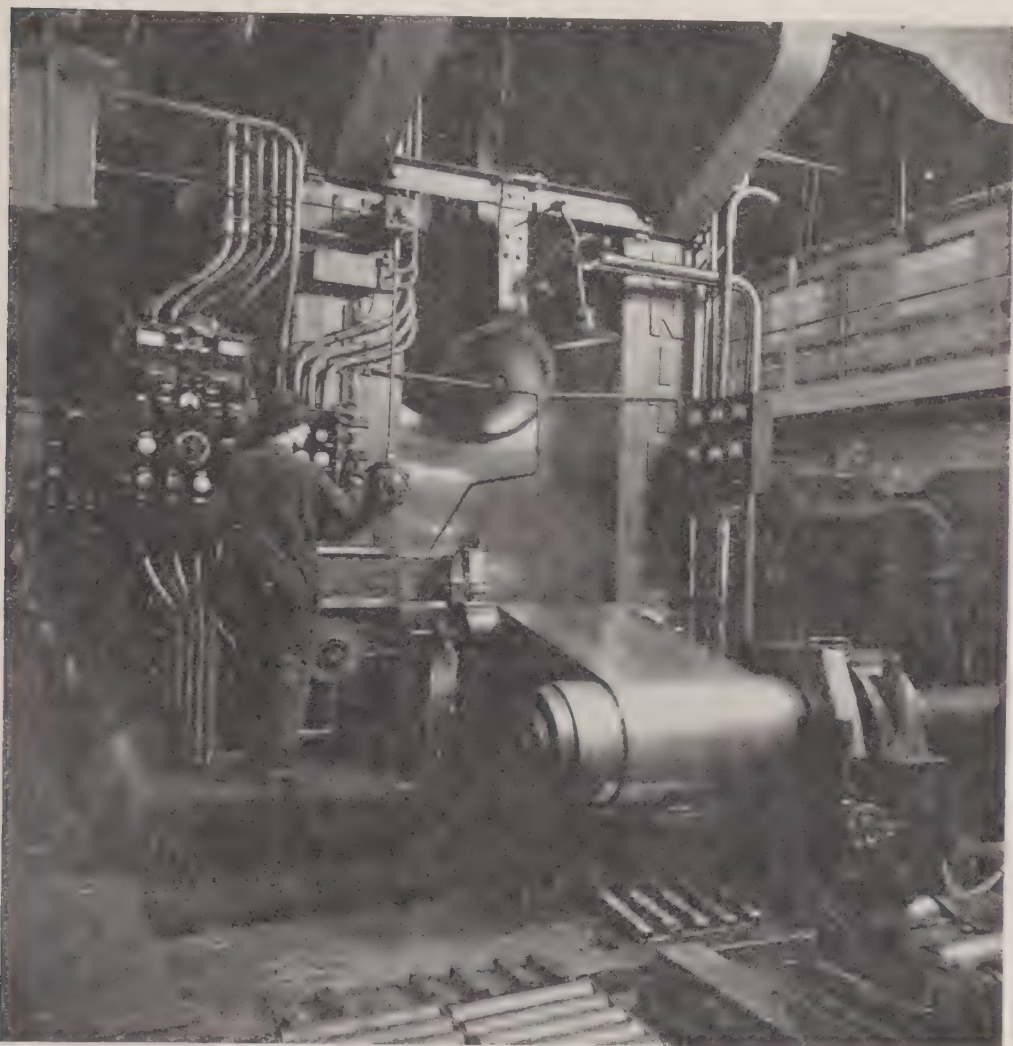
FIG. 10. Exit end of five stand tandem cold reduction mill showing control panel and flying micrometer which gives a continuous indication of the thickness of the strip being rolled.

(Courtesy Richard Thomas and Baldwins Ltd.)

are frequently of the portable-cover type Fig. 11, and consist of a base on which the coiled strip is placed and a portable cover containing the heating elements which are usually gas fired. Continuous strand-annealing furnaces are, however, coming into use and an installation of this type has been described by Siebold[8].
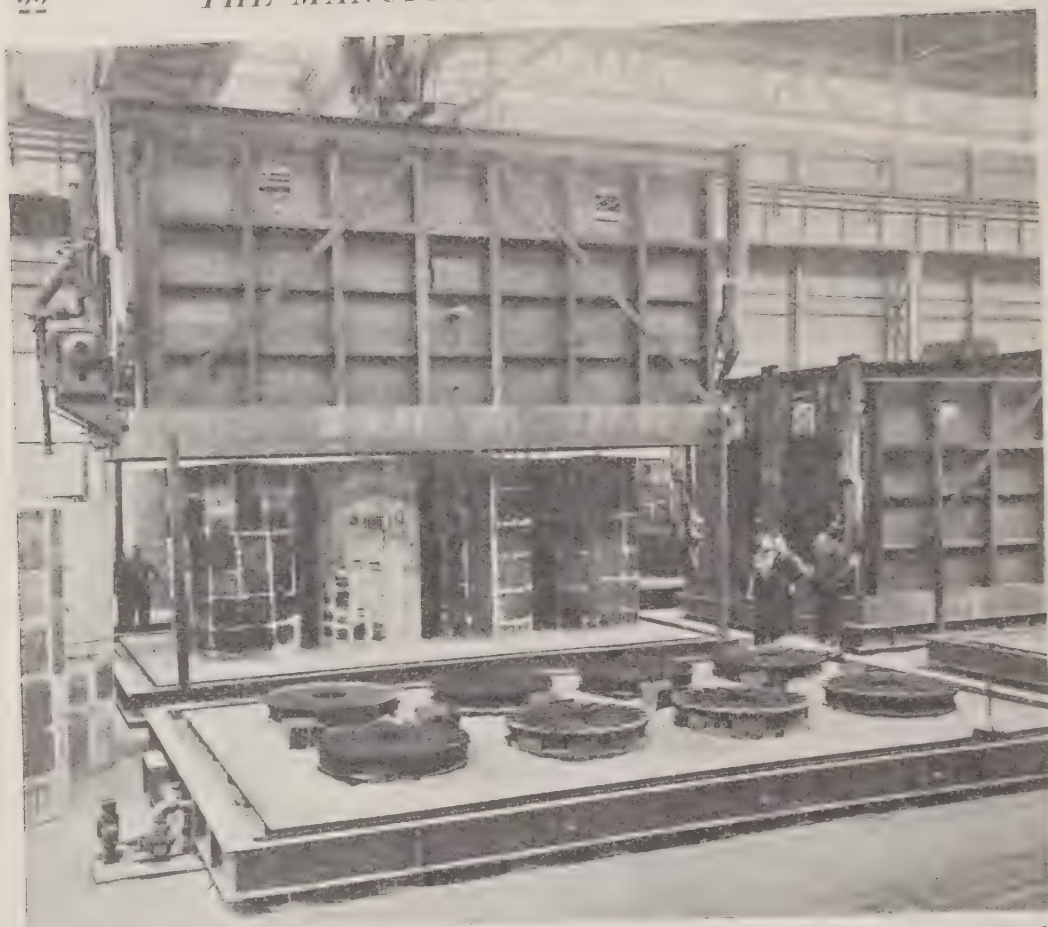
FIG. 11. Batch type annealing oven showing radiant-tube annealing cover being placed over stacks of coils.

(*Courtesy Richard Thomas and Baldwins Ltd.*)

Annealing produces a strip of steel which is extremely "soft," and if used in this condition for the manufacture of open-top cans, panelling or fluting of the bodies would result, the effect being well illustrated in Fig. 12. This difficulty is overcome by what is known as a "temper pass" in which the annealed strip is rolled under tension, the amount of reduction in thickness being of the order
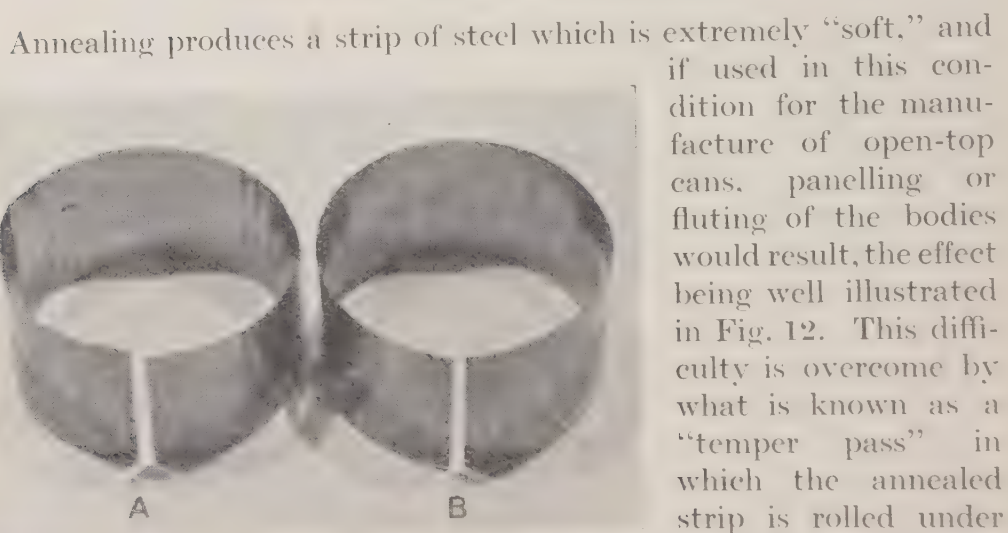
FIG. 12. Effect of "temper pass." (A) Annealed only, showing panelling or fluting; (B) Cold reduced after annealing, showing smooth bend.

(*Hoare and Hedges : "Tinplate"*)

of 3 per cent. The surface of the rolls in the temper mill has a considerable influence on the surface of the finished tinplate and consequently a great deal of attention is given to securing and maintaining the correct degree of polish compatible with the desired surface finish of the tinplate.

Tinning

The tin coating may be applied to the steel base either by hot-dipping or by electrodeposition, the latter being a process developed on a production scale during the last ten years and one which received considerable attention during the war when supplies of tin were short, as by this method it is possible to apply much lighter coatings than by the older process of hot-dipping, and thus to effect an economy in the amount of tin used for a given quantity of tinplate.

Whichever method is adopted for tinning, the sheets or strip must be free from any patches of oxide scale or grease, and this is ensured by the white pickling process which immediately precedes tinning. The process is carried out in strip or sheet form and may in general be considered as a milder version of black pickling. A batch type pickler for sheets is shown in Fig. 13.
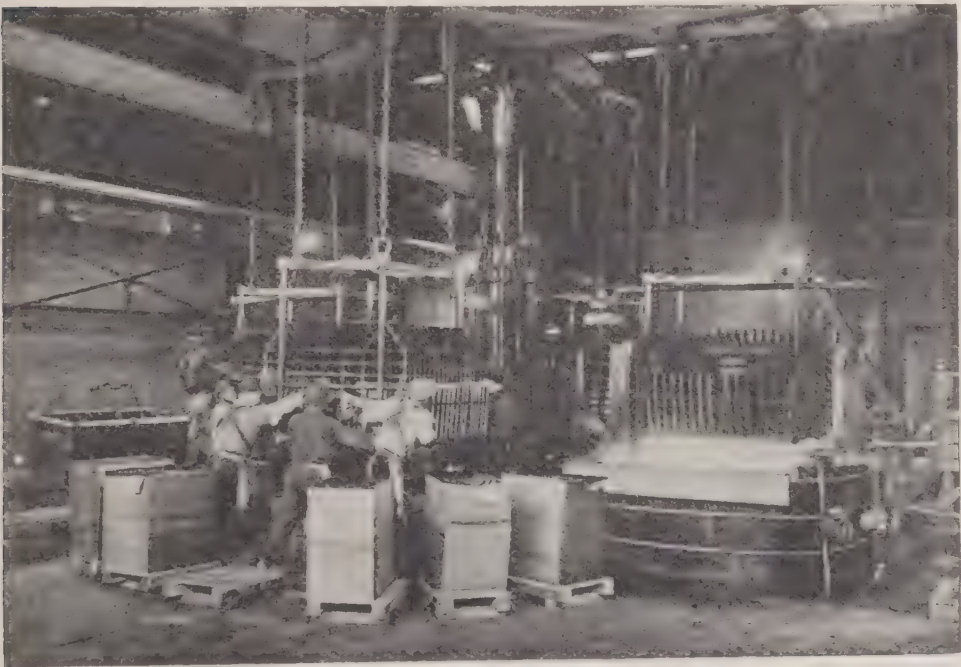
FIG. 13. Batch type pickling unit for sheets prior to tinning.
(*Courtesy Bethlehem Steel Co.*)

FIG. 14. Diagram of modern, single sweep tin-pot.

(Courtesy Wheeling Steel Corporation)   (Hoare and Hedges: "Tinplate")

Hot-dipping. A typical tinning unit is illustrated in Fig. 14 and will be seen to consist of the following essential parts :—

(1) The feed compartment where the white-pickled plates are held under water and then either automatically or manually fed into the tin-pot.

(2) The flux box where the surface of the steel sheet receives a final cleaning before tinning. The usual flux is zinc chloride.

(3) The tin-pot which holds the supply of molten tin.

(4) The grease-pot through which the tinned sheet passes after leaving the tin-pot.

There are several variations of the arrangement shown which is known as a single-sweep tin-pot. There is for example the double-sweep pot where the sheet to be tinned passes through two baths of molten tin at different temperatures.

The efficiency with which tinning is carried out determines to a large extent the corrosion resistance of the finished tinplate, and it is important to appreciate the reactions which occur during tinning and the structure of the tin coating so produced.

The structure of tinplate is well shown in Fig. 15, from which it will be seen that the coating consists of two layers on the steel base,

DIAGRAM SHOWING
CROSSECTION OF A TIN COATING
SB——Steel Base
A——Tin-Iron Alloy $FeSn_2$
T——Tin
AS——Tin-Iron Alloy with
Structure of Steel
Base Revealed

FIG. 15. A composite photomicrograph of etched samples showing the structure of tinplate.
(Courtesy American Can Co.)

the outer layer consisting essentially of unalloyed tin while the inner layer is an alloy of tin and iron, which has been shown to be almost entirely the alloy $FeSn_2$. The constitution of this alloy has been investigated by many workers, among whom may be mentioned Edwards and Preece[9], Kohman and Sanborn[10], and Hoare[11]. A review on the subject has been given by Romig[12].

The action of the flux is essentially to promote the intimate contact of the two reacting metals tin and iron, and thus to accelerate the formation of the tin-iron alloy. Hoare and Hedges[4] have pointed out that the formation of the tin-iron alloy occurs both by direct reaction between the iron and the molten tin and also by the reaction of the molten tin with the chlorides of iron formed by the reaction of the flux in the flux box. This will result in the production of tin-iron alloy as a continuous layer on the surface of the sheet, and also in the form of small dispersed crystallites. The non-adherent tin-iron allo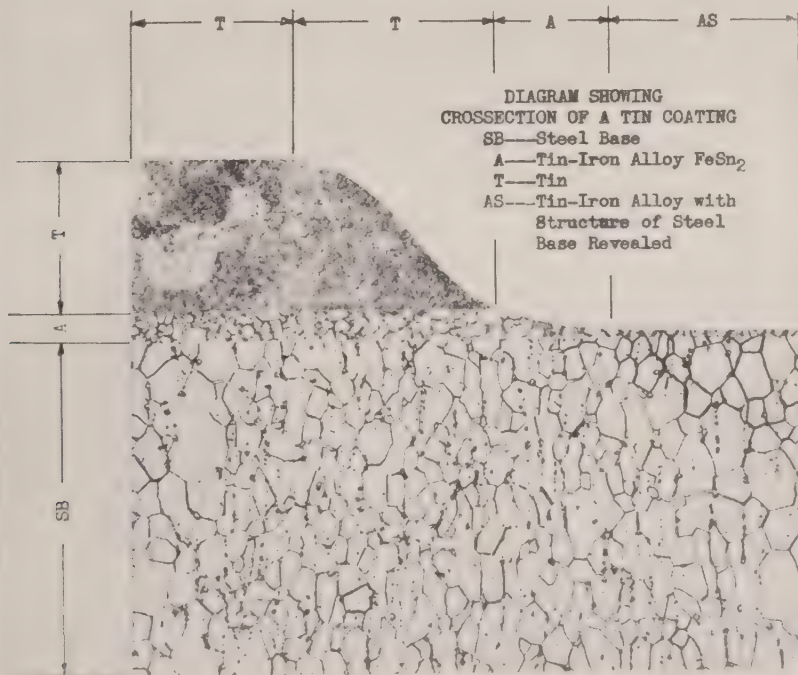y is known as "scruff" and normally tends to sink to the bottom of the tin-pot, but if it is present in excessive amounts or the temperature of the tin-pot is not properly adjusted it may be deposited on the sheets and result in a patch of roughness or a series of raised spots.

After going through the molten tin, the sheets are passed through a layer of palm oil in the grease-pot. The action of the palm oil is to control the stability of the film of tin, to prevent it contracting into small globules and to keep the surface bright and clean by preventing oxidation.

The grease-pot contains a series of rollers which are used to control the thickness of the tin coating, adjustment being effected by altering the speed and pressure of the rollers.

In some tinning units, particularly those designed for high speeds, the grease-pot rollers are equipped with brushes which assist in securing an even distribution of the tin coating.

The working temperature of the tinning unit varies considerably from mill to mill, but its accurate control is of extreme importance if uniform coatings are to be obtained. The temperature of the tin at the entry of the tin-pot is higher than that of the surface of the palm oil at the exit end of the tinning unit. This temperature gradient prevents undue oxidation of the palm oil and also of the tin coating.

As the tinned sheet leaves the grease-pot it carries with it a film of palm oil which must be removed before the tinplate is sorted and dispatched. Cleaning processes may be dry or wet or a combination of the two methods. The dry cleaning machines are known as "branning machines"—bran being the first material to be used as a cleaning agent. The machine consists of a series of flannel-covered rollers arranged in two layers, which are fed with a suitable oil-absorbent material. The two sets of rollers are run at slightly

different speeds, resulting in a scrubbing action on the surface of the sheets going through the machine, the sheets being finally freed from any residual particles by passing through a further set of rollers which are running free of cleaning material. Finally any remaining particles are removed by an air blast.

Many different types of cleaning agents have been used, but those most commonly employed are bran or weatings, with or without the addition of diatomaceous earths and similar materials. During the war it was necessary to find a substitute for the bran used, and wood flour, sawdust and flax shives were among the many materials employed.

The wet cleaning process, which in some cases may precede the dry cleaning method outlined above, usually consists of passing the sheets to be cleaned through a bath of heated detergent solution.

As in many cases tinplate used for the fabrication of open-top food cans must be lacquered, it is particularly important to ensure that the surface of the plate is completely free from grease spots or particles of cleaning material, otherwise uncoated spots may appear in the lacquer film and at some later stage may give trouble to the canner.

Electrolytic Tinning. The production of tin coatings by electrodeposition is not a particularly recent development, but it is only during the last ten years that the process has been applied to the production of the thin coatings used on tinplate.

The rapid progress made in the development of electrolytic tinning has occurred for the following reasons :—

(1) The process makes possible the tinning of continuous strip at speeds of up to 1,000 ft. per minute and with the replacement of pack rolling by the continuous cold reduction process the continuous tinning of coils of strip has become particularly desirable.

(2) Extremely accurate control of the weight of tin coating is possible and much lighter coatings can be applied than is possible by the hot-dipping method where the lower practical limit is of the order of 1.20 lb. of tin per basis box. The electrolytic process, therefore, became of great interest during the war, when the Japanese seized the Allies' main source of tin supplies and stringent economies had to be made in tin consumption.

At the present time two types of electrolyte are in common use for the commercial production of electrolytic tinplate : the acid stannous sulphate bath and the alkaline sodium stannate bath. There is also a third type, the halogen bath, but this is not in general use. Both processes have their advantages, but the alkaline bath deposits only

half as much tin per ampere hour as the acid bath and furthermore requires heating to a temperature of approximately 200 F., whereas the acid bath may be operated at room temperature. There appears to be very little to choose between the final coatings produced by the two methods and Kerr, Angles and Caulfield[13] have demonstrated, by plating under carefully controlled conditions, that there is no significant difference in the porosity of the coating produced by either method.

The actual layout of the electro-tinning line varies somewhat between individual plants and also with the process used. Hopper[14] has described a typical acid plating bath. The annealed and temper-rolled strip is welded at full operating speed to the trailing end of the preceding strip, using the slack produced in a multiple strand slack producer. The strip then passes successively through an alkaline electrolytic cleaning tank, rinse tank, hydrochloric acid pickle tank, rinse tank, acid plating tank, rinse tank, drier, oil brightening and oil quenching tanks, solvent cleaning tank and is finally recoiled.

In the line described above the plating was carried out with the strip in horizontal position, but the author states that future high speed plating lines will be designed to plate with the strip in a vertical position, thus saving a great deal of space in the layout.

The strip after plating has a dull matt surface and it is now common practice to heat the strip slightly above the melting point of tin, thereby causing the tin to flow and form a bright surface similar to that obtained by the hot-dipping process. This operation is known as flow-brightening, and in addition to altering the appearance of the plate it causes a certain amount of alloying to take place and a similar structure to that of hot dipped plate is produced, although the thickness of each layer is much less than that produced by the hot dipping process. In the electro-tinning line described above the flow-brightening is carried out by passing the plated strip through a heated oil bath and then quenching in cold oil. Among other methods used for melting the tin coating the most recent development is to use high-frequency alternating current. The temperature of the strip may be controlled by a photo-electric method which utilises the fact that the dull matt surface before flowing diffuses light while the bright surface after flowing reflects a light. The fact that the flow line is almost straight across the width of the strip is an indication that the temperature across the strip is uniform.

The proper preparation of the strip before plating is most important, as it must not only have a smooth surface, but also be completely free from rolling oils and other foreign substances. Caulfield, Kerr and Angles[15] have stated that in the alkaline bath the quality of the plating is less sensitive to pickling procedure than when the acid bath

is used. They suggest that the use of an inhibited sulphuric acid pickling bath gives the best results with the alkaline electrolyte, but that with the acid bath anodic etching in sulphuric acid is to be preferred, although pickling in hydrochloric acid is a satisfactory general method for both processes but does not give results quite as good as the two methods mentioned above.

A typical alkaline bath electro-tinning line is that operated by the Bethlehem Steel Co. The lines will take strip in widths from 20 to 33 inches. The plating line has an overall length of 150 ft. From the uncoiler the strip passes through a double-seam type electric welder, Fig. 16, which takes about 45 seconds to complete a weld. A pair of

Fig. 16. Electric welder for joining coils before plating.
(*Courtesy Bethlehem Steel Co.*)

rubber-covered pinch rolls pulls the strip from the welder and passes it to a 12 strand looping tower, Fig. 17, which has sufficient capacity to feed the line while the weld is being made to join the trailing end of one strip with the leading edge of the next.

The strip next passes through a 17 ft. long pickling tank in a series of eight vertical serpentine passes. The strip is pickled in 2.5–3 per cent sulphuric acid at a temperature of 150–170°F. The pickled strip passes into a second tank where it is washed with cold water

and then on to the plating tank which is 52 ft. long and 10 ft. deep and equipped with steam coils to heat the electrolyte to the operating temperature of 195°F.
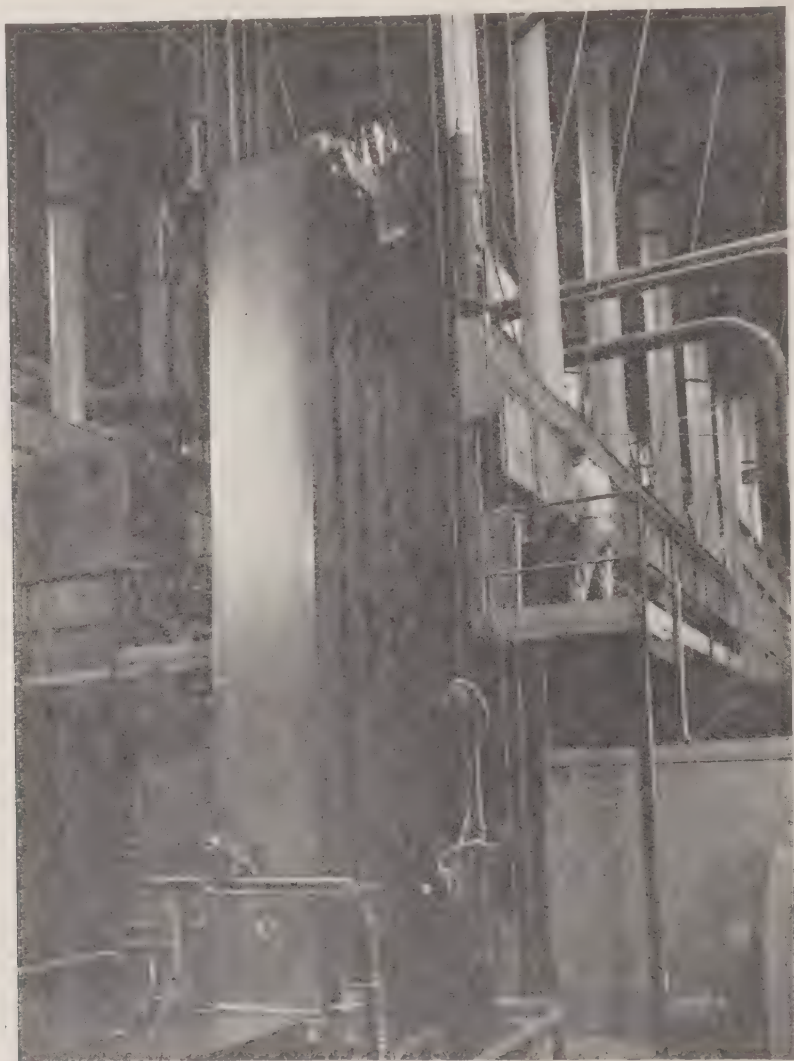
Fig. 17.   Looping tower at entry end of plating line.
(*Courtesy Bethlehem Steel Co.*)

The strip travels between twenty-four 12 inch diameter top steel conductor rolls, Fig. 18, and twenty-five 12 inch diameter rubber-covered bottom rolls giving a total of 48 vertical strands. Suspended between each strand is a tin anode weighing over a ton. The speed of the strip is governed by the width, for a 28 inch wide strip a speed of 420 ft. per minute is maintained. As the strip leaves the plating tank it passes through a set of wringer rolls and a cold water spray which rinses any dragout of electrolyte back into the plating tank.
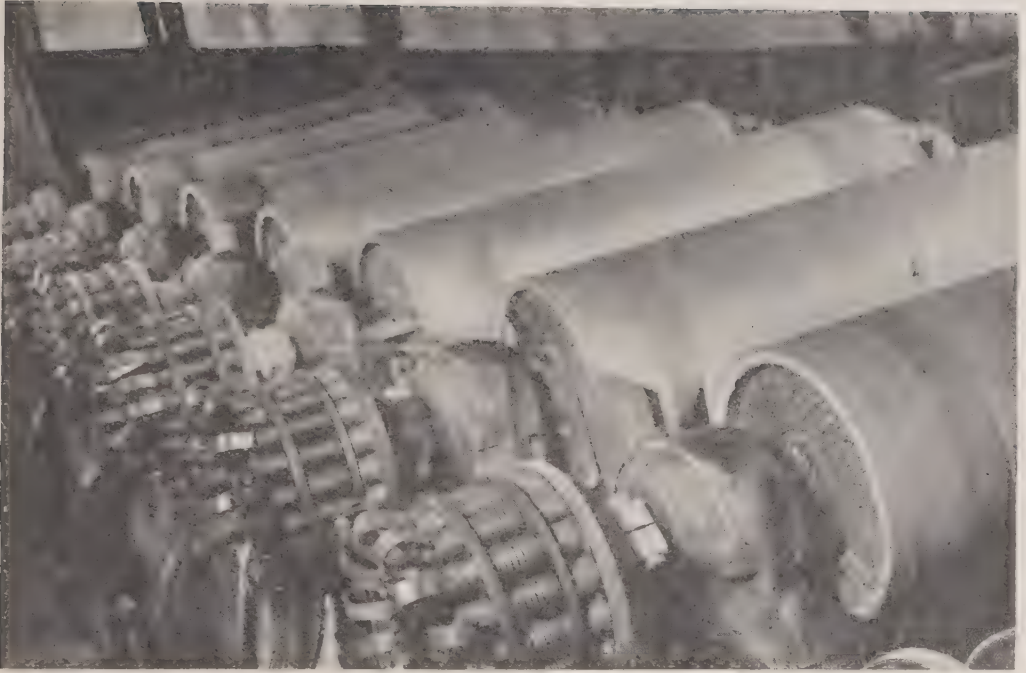
Fig. 18. Steel conductor rolls in plating line.

Fig. 19. Delivery end of plating line showing operator controlling speed, tension, load and voltage.

(Courtesy Bethlehem Steel Co.)

thus making up the loss due to evaporation. The strip next passes to a wash tank where it is washed with hot water. Coiling of the strip is carried out on a reel which floats back and forth along its axis, following any lateral movement of the strip and thus forming a straight-sided coil. The speed, tension, and voltage are all controlled from a centralised control panel at the delivery end of the strip as shown in Fig. 19.

The strip is next passed through an electrolytic cleaning bath and then flow-brightened by passage through a gas fired-radiant tube furnace, a close automatic control of the temperature being maintained by recording pyrometers. The heated strip is quenched in a water tank and passes to an electric shear where the weld is cut out, it is then coiled and sent on to the conventional sheet shearing and classifying unit and finally inspected.

The electrical equipment used in electro-tinning lines has been described by Stoltz and Cook[16], mention being made of a photoelectric device for detecting pinhole perforations in the strip and also of the equipment used for flow-brightening by the induction method.

In modern electro-tinning lines the amount of strip required to thread the line varies from 600 ft. to 1,200 ft., depending on the type of plant in use, while the strip speed may be as high as 1,000 ft. per minute, as compared with the 30 to 40 ft. per minute commonly obtained in the hot dipping of sheets.

The original electro-tinning lines were designed with the object of producing plate with a tin coating of about 8 oz. per basis box, but with properly designed equipment there is no reason why coatings of any desired thickness should not be produced. The future possibilities of electro-tinplate for the manufacture of food cans is given further consideration in Chapter 12, but there is little doubt that it will find great application in the future, and one can look ahead to the time when coils of electro-tinplate will be fed directly into the canmaking machine.

Sorting and Classification of Tinplate

The sorting and classification of tinplate is an important operation in ensuring that defective sheets are segregated before they leave the tinplate mill. Tinplate is usually classified into the following grades :—

(1)   Primes, which are sheets showing no visible defects, of correct dimensions and showing no substance variation outside agreed tolerances.

(2) Seconds or Wasters, which are plates showing a defect of such a character that they cannot be classified as primes, but may still be used for certain less exacting purposes. It is common practice for the purchaser of tinplate to accept a certain percentage of wasters with the primes, and it is generally accepted that about 75 per cent of the surface of a waster must be usable as a prime.

(3) Menders, which are plates showing a defect in the tin coating and which are sent back to the tin house for retinning.

The unit of the tinplate industry on which all prices are fixed is the "basis box." This is a unit of area equivalent to 31,360 sq. in. of tinplate, and it should be noted that this unit is entirely independent of sheet size and thickness.

The "substance" of tinplate is a term used to describe the thickness of the sheets and may be expressed in a number of ways, the most common being the weight of a basis box, in other words tinplate of 100 lb. substance indicates that a basis box or 31,360 sq. in. weighs 100 lb.

There is also a range of symbols used to express the substance, and examples with the corresponding weight per basis box are shown in Table II.

In addition to variation in substance the thickness of the tin coating may be varied, the terms "coke" and "charcoal" being used to designate certain weights of tin coating. "Best cokes" indicating a coating of $1\frac{1}{2}$ to $1\frac{3}{4}$ lb. of tin per basis box. In this connection it should be noted that it is generally recognised that a coating weight of 1 lb. of tin per basis box is equivalent to a thickness of 0.00006 in. of tin on each side of the sheet.

Recently there has been a move to specify the coating weight by the actual weight of tin present, thus C. 16, C. 20 and C. 24 indicate coating weights of 14-18, 18-22 and 22-26 oz., respectively, per basis box.

For can making, tinplate with a coating weight of 20 to 24 oz. per basis box and of substance 85 lb. to 108 lb. is most used, depending on the size of can and the product to be packed.

Hoare and Hedges[4] have referred to the following types of tinplate being used in America for can-making :—

(1) Type L, a cold-reduced plate with the general composition : C 0.06-0.10 per cent, Mn 0.30-0.50 per cent, P 0.015 per cent max, S 0.05 per cent max, Si 0.010 per cent max, and Cu 0.06 per cent. This plate is used for corrosive packs.

(2) Type L (H.E. Tested), a plate of the same general composition as above but which has passed a specified hydrogen evolution test.

(3) Type M, a hot rolled plate similar to the above but in which the phosphorus limits are raised to 0.07-0.10 per cent while the copper content may be as high as 0.2 per cent.

(4) Type MC is a plate with similar composition to type M but produced by the cold rolling process.

TABLE II

Tinplate Weights and Symbols

(Hoare)

Wt. of basis box (31,360 sq. in.) lb.	Symbol
50	Taggers
55	
60	
65	
70	Lights
75	
80	
85	
90	
95	
100	CL or ICL
107	IC "Common substance" (U.S.)
108	IC "Common substance" (U.K.)
110	
112	"112 lb."
118	
122	IXL or XL (U.K.)
125	
128	IXL (U.S.)
135	IX (U.S.)
136	IX or X (U.K.)
139	DC
148	2XL (U.S.)
155	2X (U.S.)
156	2X or XX (U.K.)

The Examination and Testing of Tinplate

The tinplate manufacturer and the can-maker carry out an exhaustive examination of the metallurgical and mechanical properties of the tinplate and there is little necessity for the canner to repeat these tests ; it is, however, desirable that cans should be examined at regular intervals to ascertain their suitability for the product to be packed, and also for resistance to internal and external corrosion.

The tinplate-producing and consuming industries use a variety of tests to assess the suitability of tinplate for a particular purpose, but the Rockwell hardness, Erichsen cupping, and the Jenkins bend tests are those most frequently employed.

The testing of sheet metals has received considerable attention, but an extensive treatment of the subject is outside the scope of this volume and the reader is directed to the excellent treatise by Jevons[17] for further information.

The thickness and continuity of the tin coating are of great interest to the canner, as these values determine to a great extent the corrosion resistance of the tinplate.

The surface of every sheet of tinplate contains a number of minute discontinuities which diminish in number as the coating weight increases. These small holes in the tin coating are called pores, and a great deal of work has been done to determine why they occur, and how their incidence may be reduced to a minimum.

A study of the origin of porosity in the tin coating has been made by Hothersall and Prytherch[18], and amongst other phenomena they found that the increase in porosity of the tinplate on fabrication appeared to be due to the increased porosity of the tin-iron alloy layer.

The relationship of porosity to tin coating thickness has been studied by Hoare[19], who found that the porosity falls off very rapidly as the tin coating approaches a value of about 1.75 to 2 lb. per basis box. It has, however, been found satisfactory to use tinplate with a coating weight lower than the above value.

Pores may be sub-divided into two classes, normal pores and potential pores. The former are defined as microscopic exposures of the steel base, while the latter may be regarded as discontinuities in the tin coating with the tin-iron alloy layer intact, and the steel base is not therefore exposed, although in subsequent fabricating operations the alloy layer may be removed and a potential pore will become a normal pore.

There are several ways of determining the continuity of the tin coating, of which the following are the most used :—

    (1)   The ferricyanide paper test.
    (2)   The hot-water porosity test.
    (3)   The thiocyanate test.
    (4)   The hydrogen evolution test.

In all types of porosity testing it is essential that the specimen to be tested should be thoroughly degreased before the test is commenced, otherwise anomalous results will be obtained. Two methods of degreasing have been described by Macnaughton, Clarke and

Prytherch[20]. In the first method, the specimen, which has been previously swabbed with a grease-solvent such as carbon tetrachloride, is immersed in a boiling 1 per cent solution of sodium disilicate (water-glass) for about one minute and then washed in running water. Freedom from grease is judged by the fact that a film of water will show no tendency to form droplets on a perfectly grease-free surface. The degreasing procedure may be repeated if the first treatment is not sufficient. The second method of degreasing consists of making the specimen the cathode of an electrolytic cell in which the electrolyte is a 1.0 per cent solution of sodium carbonate and the anode consists of strips of nickel, or, alternatively, the container for the electrolyte may be made of iron and itself act as the anode. A current of about 4 volts is passed through the cell until bubbles of gas are freely evolved from the surface of the specimen. In the case of very greasy specimens it has been found expedient to coat the specimen with a thin film of a varnish which is allowed to dry before immersion of the specimen in the electrolyte.

The ferricyanide paper test depends on the formation of a blue colour when ferrous ions react with ferricyanide ions to form a complex. The test was originally carried out by mixing the reactants with gelatine and allowing a layer of jelly to form on the specimen, but it is now common practice to carry out the test with a test paper which only requires moistening with the reactants before use. Blue spots are then produced on the test paper at the sites of the pores.

Macnaughton, Clarke and Prytherch[20] recommend carrying out this test by moistening a piece of paper about the same size as the specimen with a solution containing potassium ferricyanide (1 grm.), sodium chloride (0.5 grm.), and water (100 ml.), care being taken to see that only sufficient solution is applied to dampen the paper, otherwise if the paper is made too wet, the blue spots will tend to diffuse into each other and become obscured. The paper is placed in contact with the specimen for 1 hour, being moistened from time to time.

When the above test is applied to electrotinplate with thin tin coatings a uniform blue colour is developed, and Kerr[21] has therefore modified the test to make it applicable to this type of plate, and has suggested the following method: The specimen after cathodic degreasing is dried and placed on a sheet of glass, and a piece of paper is soaked in the same solution as described above, with the exception that 0.5 grm of Tergitol 08 is added. This serves to increase the rate of reaction and renders the paper more limp, thereby securing a better contact between the paper and the specimen. The paper is removed from the solution, drained for five seconds and laid on the specimen, any air bubbles being gently removed with the fingers. The paper is then covered with a sheet of blotting paper and

a roller squeegee run over the surface, the blotting paper is then removed and the test paper is painted with the ferricyanide solution until the surface is uniformly covered. The paper is left in contact with the specimen for ten minutes, being moistened with the ferricyanide solution if it shows signs of becoming dry.

In both the above methods the test paper is finally removed from the specimen, washed in water until all the soluble salts are removed and dried. The blue spots may then be counted and the paper kept as a permanent record of the porosity of the specimen.

In the hot water test, which was originally devised by Macnaughton, Clarke and Prytherch[20], the specimen is allowed to remain in hot water under carefully controlled conditions and the rust spots developed serve to indicate the sites of pores in the tin coating. An advantage of this test is that it may be applied to fabricated articles, as there is no necessity to have the flat surface required for the ferricyanide test.

The pH value of the water used in this test requires careful control, and Kerr[21] states that the optimum value is pH 5.0 and the permissible limits between 4.5 and 5.5. Adjustments are made by adding small quantities of N/100 HCl or N/100 sodium carbonate, depending on the direction in which it is desired to alter the pH value.

The vessel in which the tests are carried out is preferably made from tinned copper, and is fitted with a constant-level device and a thermostat to maintain a constant temperature of 95°C. The specimens to be tested are suspended in the tank for four to six hours and then removed and wiped gently with cotton wool and dried. The counting of the rust spots developed by the above technique is an extremely time consuming operation if many specimens have to be examined, and Hoare and Hedges[4] have suggested that a series of standards be prepared from tinplate of known porosity ranging from 300 to 13,000 pores per sq. dm., the surface of the specimens being wiped free from loose rust and then coated with a film of air-drying colourless lacquer. By exercising due care in comparison of the standard with a specimen of unknown porosity it is possible to obtain almost the same accuracy as by counting. A set of these standards is shown in Fig. 20. As in the ferricyanide test the application of the hot-water test to electrotinplate has caused difficulties, and Kerr[21] has developed a modified version to make it applicable to both hot dipped and electrodeposited tinplate.

In the modified form of the test advantage is taken of the phenomena noted by Macnaughton, Clarke and Prytherch[20], that during the hot water test the tin acquires an oxide film which acts as a cathode, the rust spots being formed at the anodic areas of the exposed steel base. The modified process consists, therefore, in degreasing
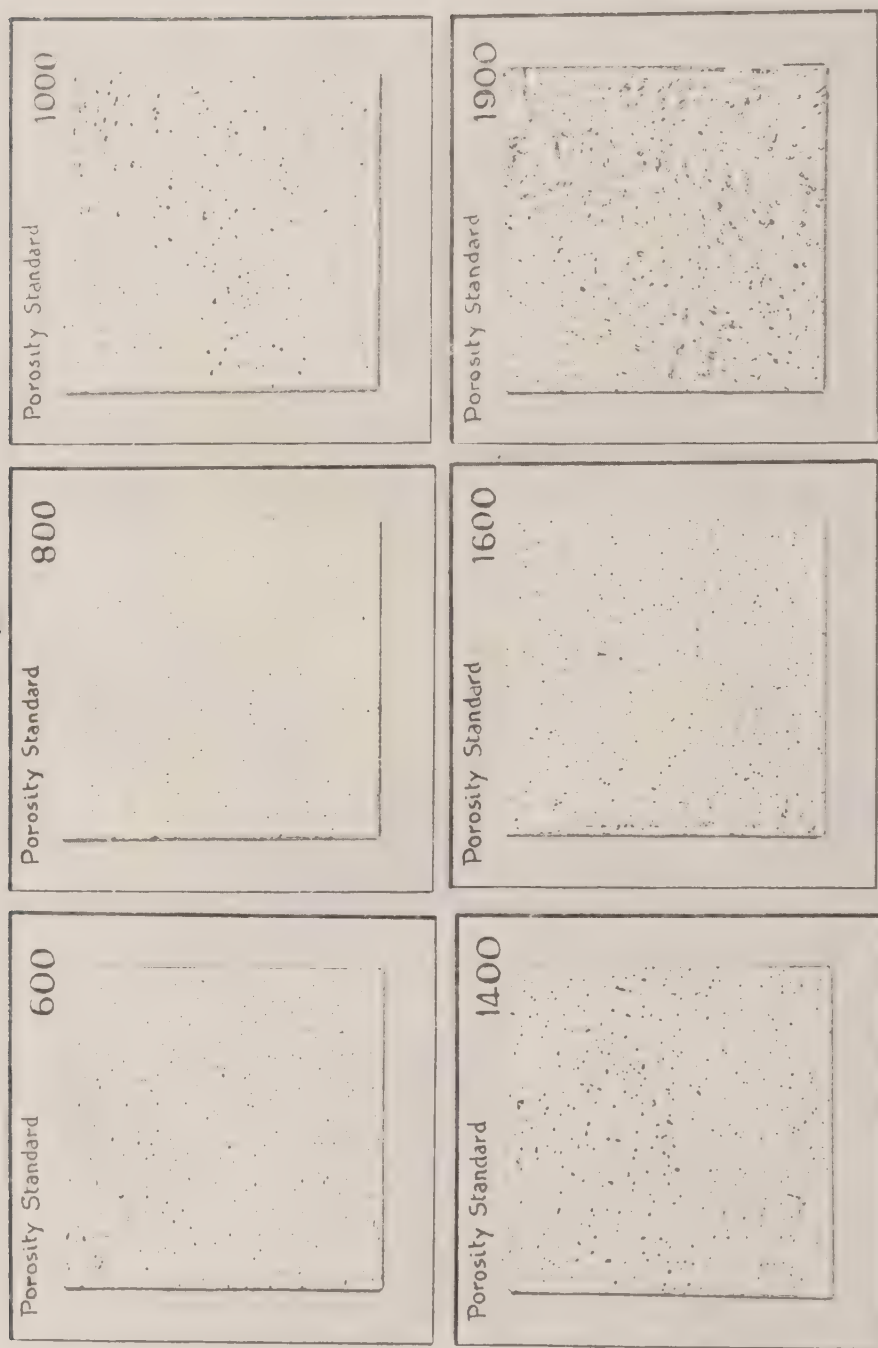
Fig. 20. Set of porosity standards covering the range 600 to 1900 pores per square decimetre. (*Hoare and Hedges : "Tinplate"*)

the specimen and then forming an oxide film on the tin surface by immersing the specimen for 5 minutes in a 10 per cent solution of chromic acid at a temperature of 90°C. The specimen is then rinsed in running water and suspended in the hot water bath as before, except that the time of immersion is reduced to 40 minutes by the filming treatment. The modified test may also be applied to hot-dipped tinplate, in which case the immersion time is lengthened to 60 minutes.

In the thiocyanate test individual pores are not revealed but an indication is given of the amount of the steel base which is exposed. In the method described by Kerr[21], the specimen (8 cm. x 6 cm.) is cathodically degreased and the edges stopped off by paraffin or Seekay wax. It is then placed in a 300 ml. tall beaker containing 250 ml. of an aqueous solution of ammonium thiocyanate 20 g., glacial acetic acid 10 g., and hydrogen peroxide (20-vol.) 10 g. per litre. The exposed iron is attacked by the acetic acid, producing a red coloration with the thiocyanate, the action being accelerated by the hydrogen peroxide, which also oxidises ferrous ions to the ferric state. The specimen is allowed to remain in the solution for 15 minutes and is then removed, the amount of iron in the solution being determined colorimetrically and the result given in terms of mg. of iron dissolved per sq. dm. of surface, due allowance being made for the area of the specimen stopped off and including both sides of the specimen.

The hydrogen evolution test devised by Vaurio, Clark and Lueck[22], is based on the rate of evolution of hydrogen when the specimen of tinplate is attacked by a N/mal solution of hydrochloric acid under standard conditions. The apparatus used consists of a corrosion cell provided with an arrangement for clamping the specimen, which for convenience takes the form of a standard-sized can end fabricated from the tinplate it is desired to examine, and a means of measuring the hydrogen evolved. The time taken to produce 5 cc. of hydrogen is designated as the "hydrogen evolution value" of the specimen. Tinplate with low hydrogen evolution values is least resistant to corrosion. The apparatus is similar in conception to that described by Morris and Bryan[23], except that in their experiments a flat disc of tinplate was used and the results did not, therefore, take any account of the effect of fabrication on the continuity of the tin coating.

From the appearance of the surface of tinplate after a test such as the hot water porosity test, it might be thought that the surface is very imperfect, in view of the number of pores per unit area, but the actual area of steel exposed is extremely small; it has, for example, been calculated by Hoare[24] that the area exposed by normal pores on an average sample of tinplate with a tin coating of $1\frac{1}{2}$ lb. per basis

box is 0.67 sq. mm. per sq. metre. It has been suggested that this figure is somewhat too low, but in any case, it is clear that in spite of the relatively large number of discontinuities the tin coating affords a very high degree of protection, and there is little doubt that future development in the cold reduction and electrotinning processes will result in continued improvement in the quality of tinplate.

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CHAPTER 3

CORROSION PHENOMENA

CORROSION is one of the chief sources of loss in the canning industry, as all types of food tend in some measure to attack the interior of the tinplate container, and furthermore, the outside of the latter may be subject to atmospheric corrosion. The principal manifestations of corrosion which are of direct interest to the canner include :—

(1) The formation of hydrogen swells or perforations with acid packs.
(2) Discoloration of the interior and/or the contents of the can with sulphur-bearing foods.
(3) Increase in the metal content of the pack.
(4) External corrosion of the can.

For an understanding of the conditions leading to the corrosion of tinplate, some acquaintance with the modern theory of corrosion is necessary, and in this chapter is given an outline of the theory insofar as it applies to the canning industry. In order that this may be intelligible to readers who are not familiar with electrochemistry, the theme is developed from first principles, but the treatment is necessarily condensed. For a more detailed exposition of the basic principles, reference should be made to any standard text-book dealing with electrochemistry, while for a comprehensive account of corrosion phenomena in general the well-known books by Evans[1], Speller[2] and others should be consulted.

The Electrochemical Basis of Corrosion

There is now general agreement that where water is present the mechanism of corrosion is primarily electrochemical, i.e., dissolution of metal takes place not by direct chemical attack, but as the effect of local electric currents flowing in closed paths between different parts of the metal surface, through the metal on the one hand and through the aqueous solution on the other. An electrochemical theory of corrosion was first propounded by Whitney[3], but in its early form this could not explain many of the phenomena encountered.

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Extensive work during the last two or three decades has led to considerable modifications and extensions of the theory without shaking its essential basis, and in its modern form it can account qualitatively for all types of corrosion phenomena, while in simple cases quantitative agreement with the theory has been found. In this chapter will be presented only such aspects of the theory as are relevant to the corrosion of tinplate.

The fundamental postulate of theoretical electrochemistry is that aqueous solutions of acids, bases and salts (known collectively as "electrolytes") contain chemically equivalent numbers of positively and negatively charged particles or "ions," which are formed by the "dissociation" of uncharged solute molecules. These ions are free to move independently, and under the influence of an electromotive force ("E.M.F.") they migrate in one or other direction according to the sign of the charge. Positively charged ions move in the direction of the E.M.F. as conventionally defined, and are termed "cations," while negatively charged ions move in the opposite direction and are termed "anions."* Acids yield as cations hydrogen ($H^{\cdot}$) ions, and as anions either halogen (chlorine, bromine, etc.) ions or negatively charged radicles such as nitrate (NO_3), sulphate (SO_4) or phosphate ($PO_4^{'''}$). Bases yield as cations metal ions or positively charged radicles such as ammonium ($NH_4^{\cdot}$), and as anions hydroxyl (OH) ions, which are also produced together with hydrogen ions by the dissociation of water itself. A salt, being formed by the neutralisation of an acid with a base, yields the same cations as the corresponding base, and the same anions as the corresponding acid. The movement of ions under the influence of an E.M.F. actually constitutes an electric current through the liquid, the measured current being the sum of the contributions due to the cations and to the anions, respectively, and it is to be noted that this "electrolytic" conduction involves a movement of matter as well as of electricity.

Electrolyte solutions, then, are able to conduct electricity, but the mechanism of conduction differs from that in metals, which are now believed to yield metal ions (positive) and free electrons (negative). Under the influence of an E.M.F. the electrons migrate through the framework of metal ions, this movement constituting "electronic" conduction, but there is no simultaneous movement of matter as in electrolytic conduction. In order to include an electrolyte solution in an electric circuit, connection is made to metal "electrodes" in contact with the solution, and it follows from the above that at the boundary surface between an electrode and an electrolyte solution

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* The charge on an ion is opposite or equal to a simple multiple of the (negative) charge of an electron, and in the chemical formula of the ion each unit charge is denoted by a dot if positive, and by a dash if negative.

there is a transition from electronic to electrolytic conduction or vice versa. At the electrode (termed the "anode") where in the conventional sense the current enters the solution, the E.M.F. will produce within the metal a migration of electrons *away from* the boundary surface, and in the simplest case this will leave metal ions free to pass into solution and migrate through the liquid, away from the electrode surface. Correspondingly, at the other electrode (the "cathode") there will be within the metal a migration of electrons *towards* the boundary surface, and cations reaching the electrode surface from the solution will be immobilised in numbers electrically (and chemically) equivalent to the cations passing into solution at the anode. The simultaneous migration of anions (a) towards the anode, and (b) away from the cathode, balances the charges, which would otherwise be built up in the solution, by the formation of cations at the anode and the deposition of cations at the cathode, so that overall electrical neutrality is maintained in all parts of the solution. (Fig. 21 illustrates the terms defined above.)
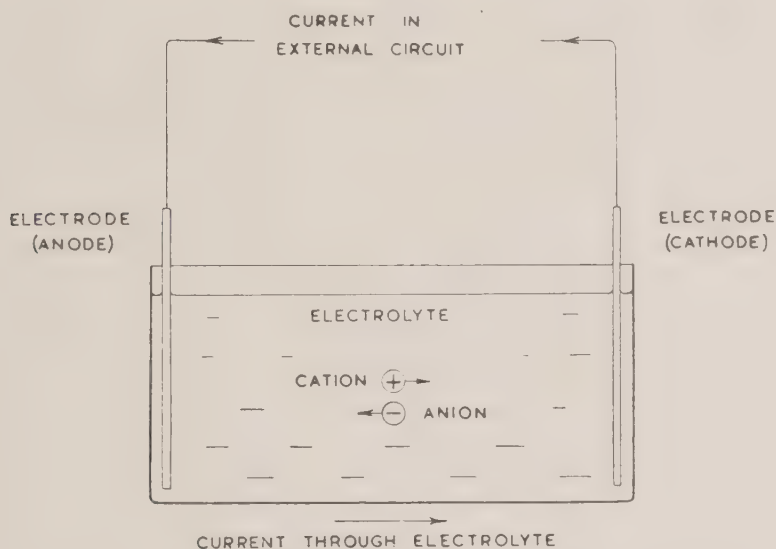
Fig. 21. Schematic diagram of electrolytic conduction.
(*Sumner*)

A second postulate of classical electrochemistry, which has been modified in recent years but still affords the most convenient means of treating electrode phenomena, is that at an electrode surface the transition from electronic to electrolytic conductivity is (in general) associated with a difference in electrical potential between the electrode and the solution. This means that the "electrode reaction" (i.e., the interaction between ions and electrons at the electrode

surface) involves a change in chemical energy and will tend to occur spontaneously in one direction, whereas energy from a separate source must be supplied to cause the reaction to proceed in the opposite direction. The "electrode potential," as this potential difference is called, is determined by the nature of the electrode reaction ; it is a function of the concentration of the ions concerned in this reaction, and where these are ions of the electrode metal (as with, say, a copper electrode in copper sulphate solution) it is also characteristic of the metal itself. For a metal in contact with its own ions the ease of deposition of the ions will be increased, and the ease of passage into solution decreased, by an increase in metal ion concentration.

When two different metals are immersed in the same solution (e.g., zinc and copper in dilute sulphuric acid), in general they will have different potentials against the solution (see later). If the two electrodes are connected through an external conductor, there will be a *spontaneous* flow of electric current through the external circuit and a corresponding current through the solution, the direction of the current being such that the electrode at which metal ions pass more readily into solution functions as *anode*. In the example quoted, zinc is anode and the anodic reaction consists in the passage of zinc ions into solution, but since the solution does not contain copper ions the only reaction possible at the cathode is the combination of hydrogen ions with free electrons to give uncharged hydrogen atoms, these combining to molecules of hydrogen gas which is evolved as such. The nett effect of the two electrode reactions is that the chemical energy of the system as a whole is reduced, and energy released by the spontaneous chemical change appears in the form of electrical energy. A flow of electrons in the external circuit is essential to the continuation of the process, since it serves to remove or neutralise the charges which would otherwise be built up on the electrodes by the passage of cations into solution at the anode and the deposition of cations at the cathode. The system just described is an example of the "voltaic cell" or "galvanic cell," and each electrode with its associated electrolyte is termed a "half-cell" or "half-element." A voltaic cell, in general, is a source of E.M.F. and may be obtained by the combination of any two half-elements which have different electrode potentials, but in the present chapter only certain types of combination will be considered.

It is not possible to determine the absolute value of the potential difference at a single electrode, but by combining various half-elements with a standard half-element of reproducible potential and measuring the E.M.F.'s of the resulting cells, electrode potentials can be compared with reference to an arbitrary zero. The electrode

potential of a metal in contact with its own ions is of theoretical importance and is usually "reversible," i.e., for small current densities* the potential is practically independent of the direction of the current, or in other words, of whether the electrode acts as an anode or as a cathode. Special significance attaches to the potential set up by the equilibrium, at a metal electrode, between hydrogen gas and hydrogen ions, which are the cations characteristic of acids and are present in aqueous solutions generally. Mention has been made above of the production of hydrogen gas by the discharge of hydrogen ions at a cathode, but the converse transformation of hydrogen gas to hydrogen ions at an anode can also be achieved. A metal electrode is necessary as a vehicle for the combination or separation of hydrogen ions and electrons on the one hand and of hydrogen atoms on the other, but since the metal undergoes no nett change (i.e., it acts as a "catalyst"), theoretically the equilibrium should not depend on the particular metal used. In practice this is not true, and the potential of the "hydrogen electrode" is reversible, in the sense defined above, only when a powerfully catalytic metal such as "platinised" platinum (platinum coated with finely divided platinum black) is used as the electrode material. At other metals the potential at which the cathodic evolution of hydrogen begins is markedly different from the potential of a reversible hydrogen electrode in the same solution, and this difference is known as the "hydrogen over-potential" for the metal surface in question. The potential of the reversible hydrogen electrode depends both on the hydrogen ion concentration and on the hydrogen gas pressure, but is usually referred to a pressure of one atmosphere since this corresponds with gas evolution under ordinary conditions.

The reversible potential of a metal against a "normal" (N/) solution of its own ions, i.e., a solution containing 1 gram-equivalent† of metal ions per litre, is known as the "standard" or "normal" electrode potential of the metal concerned, and when the metals and hydrogen are arranged in order of their normal electrode potentials there is obtained the "electromotive" or "electrochemical" series (Table III). It will be seen that the metals fall in order of their chemical reactivities, the most reactive or "base" metals (the alkali metals) being at one end of the series and the least reactive or most "noble" metals (the platinum metals) at the other. Hydrogen occupies an intermediate position and its normal potential is taken as an arbitrary zero. In this country it is usual to designate potentials more

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* The current density at an electrode is equal to the total current divided by the area of the electrode.

† The equivalent weight of a cation is its atomic (or molecular) weight, divided by the number of electrons required to neutralise a single cation.

TABLE III

The Potential Series of the Metals at 25°C.

(Evans)

Metal	Ion considered	Normal Electrode Potential Volts
Gold	Au···	1.42
Platinum	Pt··	1.2
Silver	Ag·	0.7995
Mercury	(Hg₂)···	0.7986
Copper	Cu··	0.3448
Hydrogen (1 atm.)	H·	0.0000
Lead	Pb··	0.126
Tin	Sn··	0.136
Nickel	Ni··	0.250
Cadmium	Cd··	0.4020
Iron	Fe··	0.440
Chromium	Cr··	0.71
Zinc	Zn··	0.7620
Aluminium	Al···	1.67
Magnesium	Mg··	2.34
Sodium	Na·	2.712
Potassium	K·	2.922
Lithium	Li·	3.02

base than that of the normal hydrogen electrode as negative, and more noble potentials as positive. Not all the potentials shown in the table can be measured experimentally, those of the alkali metals, for example, being unrealisable, but they can be calculated from other data by thermo-dynamical methods.

The significance of the electromotive series has often been exaggerated, for the standard potentials all refer to normal ionic concentrations, and for metals not too far apart in the series the order of the electrode potentials can be reversed by suitably choosing the ionic concentrations. (An increase in metal ion concentration makes the potential more noble, and vice versa.) When two different metals are immersed in a solution not containing the ions of either, it usually happens that in the voltaic cell thus formed the metal with the less noble *standard* electrode potential functions as anode, but this is by no means universal, as will appear when the corrosion of tinplate in fruit acids is considered. In the example already quoted (zinc and copper in dilute sulphuric acid), zinc functions as anode, but copper

is not involved in the cathode reaction except for its effect on the potential at which hydrogen is evolved. This system acts as a voltaic cell, therefore, not because zinc is anodic to copper as such, but because the zinc potential is more base than that of hydrogen in the same solution, taking the overpotential at copper into account. Where each metal is immersed in a solution of its own ions, e.g. zinc in zinc sulphate and copper in copper sulphate (the solutions being in contact but in such a way as substantially to prevent mixing), zinc still functions as anode, but the cathodic reaction is the deposition of copper and the potential is determined by the copper ion concentration. This combination finds practical application in the well-known Daniell cell.

Reversible electrode potentials are measured under "open-circuit" or "no-current" conditions, and except at very low current densities the passage of current through the cell causes the electrode potentials to deviate from their reversible values. Such a deviation is termed "polarisation"; when the potential becomes more noble the electrode is said to be "anodically polarised," while when it becomes more base the electrode is said to be "cathodically polarised." In its simplest form, known as "concentration polarisation," this change in potential arises from the fact that the passage of current alters the ionic concentrations in the layers of liquid immediately in contact with the electrodes. At the anode, for example, the concentration of cations in proximity to the electrode surface will reach a steady value, which is *greater* than that in the bulk of the solution, when the rate of formation of new cations is balanced by (1) the migration of cations away from the region of the anode, under the influence of the E.M.F., and (2) ordinary diffusion of the electrolyte as a whole (anions + cations) from the region of high concentration at the anode to the lower concentration in the bulk of the solution. Since the anode potential is determined by the cation concentration at the metal surface, it will become more noble. In a similar way, the cation concentration at the cathode surface will reach a steady value which is *less* than that in the bulk of the solution, and the cathode potential will become more base. The effect of polarisation at one or both electrodes in a voltaic cell is thus to bring the potentials closer together, i.e., to reduce the available E.M.F. Other examples of polarisation, of which hydrogen overpotential is of chief interest in relation to corrosion, may arise when the electrode reaction itself is more complex than the direct transfer of metal ions from the solid state into solution, or vice versa.

All types of polarisation increase with the current flowing (or more strictly, with the *current density* at the electrode concerned), but are diminished by a rise in temperature. On the other hand, the presence

of an oxidising agent in the solution enables the cathodic production of hydrogen gas to be partly or wholly replaced by an oxidation-reduction reaction involving an equivalent electron transfer, which can proceed at a less base potential, for a given current density, than is required when hydrogen evolution is the only possible process. The nett effect is that the oxidising agent is reduced, and some or all of the hydrogen is oxidised to water instead of being evolved as gas. When a cathodic reaction is caused to proceed at a less base potential, or an anodic reaction at a less noble potential, for a given current density, the electrode is said to be "depolarised," and the effective agent is termed a "depolariser." Oxidising agents are thus depolarisers for cathodic reactions involving hydrogen.

The application of these principles to the corrosion of a single metal, in a solution containing anions which do not form an insoluble compound with the metal, may now be considered. In general, the potential difference between a metal and an electrolyte solution is not completely uniform over the metal surface, and local currents are set up between areas of different potential, since the anodic and cathodic areas are connected externally through the body of the metal. Such local potential differences can arise in many ways, but in acid solutions, which dissolve surface films of oxide, the most important factors are :—

(1) Inclusions in the metal, of impurities having (usually) a more noble potential than the basis metal.
(2) Mechanical differences between different areas of the metal, strained areas being anodic to unstrained areas.
(3) Heterogeneity of crystal structure, giving rise to differences of reactivity at grain boundaries, differently oriented crystal faces, etc.

In neutral or nearly neutral solutions, local variations in the air-formed oxide film which is usually present on the metal surface, and/or differences in accessibility to oxygen, may assume major importance.

Since each local voltaic element is short-circuited, its circuit resistance will be virtually that of the path through the liquid. When contact is first made between the metal and the solution, the current in any given local element will be determined by the "open-circuit" E.M.F. of the element and the resistance of the liquid path, but with the passage of current polarisation will develop, so that the effective E.M.F. and therefore the current will fall until a steady state is reached. The current flowing will then maintain the polarisation at the two electrodes at values such that the residual E.M.F. just suffices

to drive the steady current through the circuit resistance. In Fig. 22 are shown diagrammatically the "polarisation curves" for the electrodes of a voltaic cell or local element, the electrode potential in the steady state being plotted against the corresponding current, and the effective E.M.F. for any value of the current is given by the vertical distance between the two polarisation curves. With an electrolyte of good conductivity the residual E.M.F., i.e. the difference in potential between the anodic and cathodic areas, will become very small, so that the steady current will have a value very close to that at which the two polarisation curves intersect. Correspondingly, the metal as a whole will show a potential, with respect to
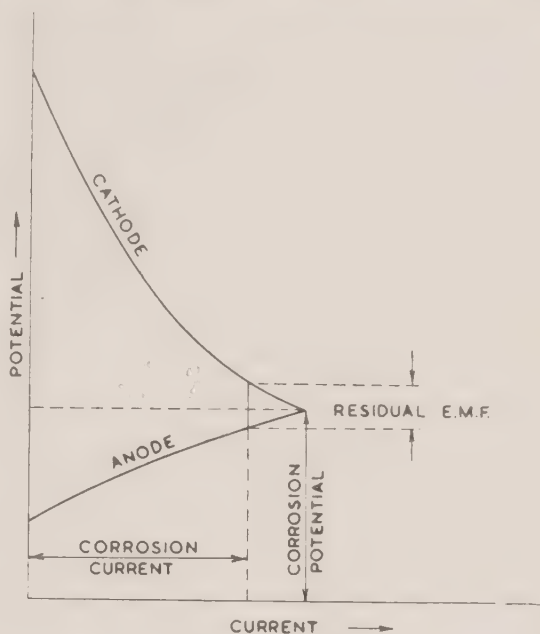

FIG. 22.   Polarisation curves for corrosion element (schematic). (*Sumner*)

the solution, which is an overall mean value for the anodic and cathodic areas distributed over the surface, and approximates to the potential at the intersection point. In this way the metal attains a definite "corrosion potential," even though the solution does not contain its own ions initially. At the anodic areas metal ions pass into solution, i.e., the metal corrodes, while at the cathodic areas (in most corrosion processes) hydrogen is evolved or oxidised, and in the layer of liquid contiguous to each anodic or cathodic area the ionic concentration will reach a steady state as already described.

In the absence of an oxidising agent, voltaic elements of this type can be set up only if the potential of the anodic areas is more base than that of hydrogen in the same solution, taking over-potential at the cathodic areas into account. In practice this means that even in strongly acid solutions, only metals having *normal* electrode potentials more base than that of hydrogen can dissolve with the evolution of hydrogen. For metals more noble than hydrogen in the electromotive series, or in solutions of low hydrogen-ion concentration, anodic dissolution can proceed only if some depolariser (oxygen or an oxidising agent) is present at the cathodic areas, to remove hydrogen by oxidation. This function can be discharged by dissolved oxygen where the corroding system is exposed to the atmosphere,

and the magnitude of the "corrosion current" will then be controlled by the rate at which oxygen can diffuse to the cathodic areas, i.e., the cathodic polarisation curve will represent a type of concentration polarisation involving dissolved oxygen.

When two dissimilar metals are in contact in the same solution, there may still be corrosion of each metal by "local action" according to the above mechanism, but there will also be a "couple" effect depending on the relation between the separate corrosion potentials of the two metals in the solution concerned. The metal with the more base corrosion potential will become anodic to the other metal and current will flow in the couple, with the effect that the individual corrosion potentials of the two metals will be altered in a similar way to the potentials of the anodic and cathodic elements in a single metal, i.e., the potentials will be brought closer together by the passage of current, until in the steady state the residual E.M.F. just suffices to maintain the current flowing in the couple. At each electrode this shift in the corrosion potential will be associated with a reduction in the local currents flowing between different areas of the same metal, and if the current density due to the couple is large enough the local currents will be suppressed altogether, the whole electrode surface becoming polarised in the same sense, anodically or cathodically as the case may be.

The thesis of the modern electrochemical theory of corrosion, therefore, is that the rate of corrosion of a metal is controlled by the magnitude of the local currents flowing between areas of different potential, these currents in turn being determined by electrochemical relations such as those outlined above. As shown in Fig. 22, a major role is played by polarisation, and any factor which increases either anodic or cathodic polarisation, or both, will have a retarding effect on corrosion ; conversely, any factor which reduces polarisation will accelerate corrosion. Factors which reduce cathodic polarisation include high concentration of hydrogen ions (i.e., acidity), small hydrogen overpotential, and accessibility to oxygen or oxidising agents. Anodic polarisation is reduced by the presence of "accelerators" (anodic depolarising agents) and increased by the presence of "inhibitors." Inhibitors are commonly used to reduce the loss of metal in acid pickling processes, and compounds of many diverse types have been claimed to be effective. Many of these are colloidal substances which are negatively charged in acid solution and are probably adsorbed on the anodic areas, thereby reducing the effective "electrode" area ; this increases the polarisation produced by a given current, since polarisation depends on the current density, which is inversely proportional to the electrode area. Accelerators are more specific in action, and one example affecting the corrosion of tinplate

is mentioned below. Both anodic and cathodic polarisations are reduced by elevation of the temperature, which is thus a factor favourable to corrosion.

The effect of these various factors can be seen graphically by means of diagrams such as Fig. 22, which have been much used by Evans[1], Hoar[8] and others in interpreting corrosion phenomena. Thus the effect of decreasing the hydrogen ion concentration or of increasing the hydrogen overpotential is to shift the whole cathodic curve nearer to the anodic curve, so that the curves intersect at a lower value of the current. A decrease in anodic area causes the anodic polarisation curve to rise more steeply, again diminishing the current corresponding with the intersection of the curves. Elevation of the temperature reduces the slope of both curves and intersection occurs at a higher current value, and so on.

The Corrosion of Tinplate in Acid Media

Tinplate of the quality used in canning has too thin a coating of tin for perfect coverage of the steel, which is exposed at pores or other discontinuities in the coating even before fabrication of the can. During fabrication, further damage to the coating occurs, especially at seams and corrugations. While, therefore, with unlacquered tinplate the main area of metal in contact with corrosive agencies is tin, at each discontinuity a short-circuited voltaic element or "couple" is set up between the tin and the steel, and the behaviour of this couple is of great importance. With lacquered tinplate, however, tin hardly comes into the picture, and corrosion is virtually confined to the steel which is, or becomes exposed at discontinuities in the lacquer coating.

In considering the electrochemical relations of tin and iron (or steel), the following facts are of importance :—

(1) Both tin and iron are more base than hydrogen in the electromotive series, but the normal potential of iron is more base than that of tin.

(2) The two metals are fairly close together in the electromotive series.

(3) The hydrogen overpotential at tin is relatively large, but at iron is relatively small.

As might be expected from its position in the electromotive series, iron dissolves readily in acids with the evolution of hydrogen, but this is not true of tin since the large overpotential makes the corrosion current and, therefore, the rate of hydrogen evolution, very small except in very strongly acid media. The attack of tin by dilute
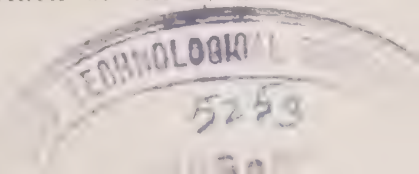
organic acids (such as occur in fruit) is therefore practically negligible
in the absence of air or an oxidising agent, which depolarises the
cathodic reaction and increases the rate of acid attack many times.
As indicated, such a depolariser is not necessary for the corrosion of
iron in the same media, but is an accelerating factor when present.

It was for a long time assumed that iron must be anodic to tin in
any electrolyte, but Mantell and King[4] found that while a tin-iron
couple immersed in any of several strong electrolytes gave *initially*
an E.M.F. indicating that iron was anode, this E.M.F. reversed after
a few minutes and the iron became the *cathode*.   This observation,
which was confirmed by Kohman and Sanborn[5], Lueck and Blair[6],
and Morris and Bryan[7], received no convincing explanation until
the behaviour of the tin-iron couple in dilute acid media was eluci-
dated by Hoar[8], who measured the *individual* corrosion potentials of
tin and iron, both separately and in couple, as a function of time.
Hoar[8] showed that each metal had a relatively noble potential when
first immersed, this being due to the oxide film initially present on
the metal surface, but as the film dissolved in the acid solution the
potential fell rapidly to a steady value characteristic of the bare metal.
The relation of the initial to the final potential depended on the
electrolyte.   In solutions containing citric acid, oxide-covered iron
was more base than oxide-covered tin, but the reverse was found in
sulphuric acid ; on the other hand, the final corrosion potential of
iron in weak organic acids (citric or oxalic) was more noble than that
of tin, whereas in sulphuric acid it was more base.   Hence in citric
acid iron was initially anodic but finally cathodic, while in sulphuric
acid it was initially cathodic but finally anodic.   In oxalic acid, no
reversal could be detected.   Hoar's explanation is that the important
factor determining the relation of the corrosion potential of tin to that
of iron, is whether tin ions passing into solution remain as such or are
largely removed as negatively charged complexes formed with the
acid anions ; such complex formation reduces the tin concentration
to a very low value, so that the potential of the anodic areas of the
tin, and hence the corrosion potential, is more base.   In sulphuric
acid, complexes are not formed and tin has a more noble corrosion
potential than iron, but in organic acids such as those occurring in
fruit, complexes are formed and the corrosion potential of tin is more
base than that of iron.   It was also shown by Hoar[8] that when tin and
iron were coupled together, the corrosion potentials approached one
another as already described ; in solutions of citric acid + sodium
citrate ("citric buffer") for instance, tin was anodic and corroded more
rapidly when coupled than when alone, the increase in corrosion being
quantitatively equivalent to the current flowing in the couple.
Correspondingly, the iron corroded less rapidly when coupled with

tin, but local action on both metals still played an important part in the total corrosion. Fig. 23, from Hoar's paper, strikingly illustrates both the "reversal" of E.M.F. and the effect of coupling the two metals in a citrate buffer solution. In Fig. 24, also after Hoar[8a], is shown the general effect of the corrosion of tinplate, according as tin is anodic or cathodic to steel.
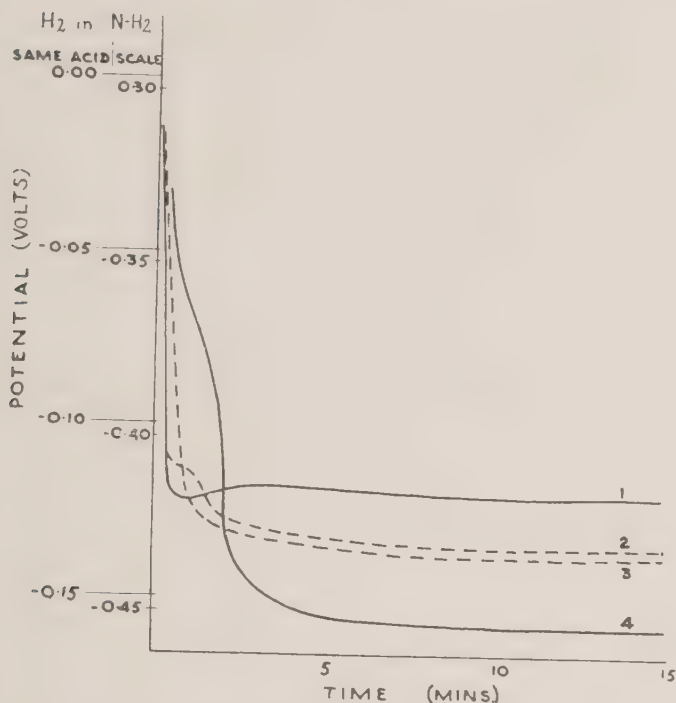

FIG. 23. The above curves illustrate the changes in potential which occur in the two metals tin and iron when immersed in 0.1 M. citric buffer at pH 5.10.

    1. Iron
    2. Iron }
    3. Tin } Coupled
    4. Tin

        (Hoar)
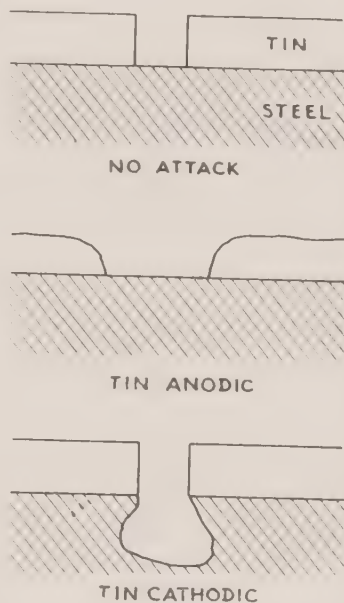
FIG. 24. Diagrammatic representation of the general effect of the corrosion of tinplate. When tin is anodic etching of the tin and protection of the steel base will occur. With tin cathodic, the steel base will be attacked, while the tin coating will be left unaffected, although it may acquire a thick oxide film.

(Hoar)

This behaviour is of prime importance in the canning industry, and undoubtedly accounts to a large extent for the serviceability of plain cans as containers for acid fruits. Under these conditions tin is anodic, and because of the limited availability of oxygen inside the can the corrosion of tin is mainly that due to coupling with the steel, this corrosion in turn being controlled by the rate at which hydrogen can be evolved at the steel. Since the area of the tin is very large as compared with that of the exposed steel, the total tin corrosion is widely spread and the *depth* of attack is very small; on the other hand, the relatively small area of the steel cathodes means that

considerable polarisation is set up by quite small corrosion currents, so that the rate of hydrogen production is slow. Corrosion in un-lacquered fruit cans usually takes the form of a slight general "feathery" etching of the tin, with local attack of the steel base at the most exposed areas, such as the seams. On the other hand, in lacquered cans there is a tendency for discontinuities in the lacquer film to coincide with discontinuities in the tin coating, where steel is directly exposed, and even where tin is exposed the area is of the same order as that of the steel, so that a relatively small total dis-solution of tin will remove the coating at the unlacquered spots. In lacquered cans, therefore, the important factor is the corrosion of the steel itself, and since the steel is attacked over separate small areas, failure takes the form of small perforations.

With actual fruit packs, various complicating factors arise, and the behaviour may be profoundly influenced by particular constituents or impurities in the fruit and other materials (especially sugar) used in canning, as well as by the kind of steel from which the tinplate is made. Many investigators, including Kohman[9], Culpepper[10] and their co-workers in America, and Morris and Bryan[11] in this country, have accumulated a mass of well-authenticated data on the effects of a wide variety of factors, including acidity (hydrogen-ion concent-ration or pH*), accelerators and inhibitors, and steel composition, but this work has related mainly to corrosion *rates*, and some of the findings are not easy to interpret on this basis alone. Hoar[8] and his collaborators have measured both corrosion potentials and corrosion rates (the latter giving a measure of corrosion currents), and by this means have been able to distinguish between factors which influence the anodic reaction and those which influence the cathodic reaction. This approach, by concentrating attention on the *mechanism* of the corrosion process, has afforded a rational explanation of many previously obscure results, as well as confirming earlier work.

The early experiments of Morris and Bryan[7] were concerned with the corrosion of tin, iron and the tin-iron couple in citric acid or citrate buffer solutions, and exemplified the behaviour already described, viz., (a) the accelerated corrosion of either metal singly with increase in acidity, (b) the negligible corrosion of tin in air-free solutions of weak organic acids, (c) the accelerating effect of oxygen (especially with tin), (d) the effect of coupling the metals in increasing the corrosion of tin and decreasing that of iron, the evolution of hydrogen occurring only at the iron member of the couple. Morris

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* The symbol "pH" denotes $-\log_{10}$ (hydrogen ion concentration expressed as normality), e.g., if the hydrogen ion concentration 10^{-5}N, the pH value is 5. It is to be noted that as the hydrogen ion concentration increases, pH *decreases*. A neutral solution has a pH value of 7 ; acid solutions have pH values below 7, alkaline solutions pH values above 7.

and Bryan[7] also showed that the *total* corrosion of the couple was always less than that of a similar area of iron alone, and tended to diminish with decreasing acidity, but the distribution of the total corrosion between the tin and iron varied with pH. In air-free solutions there was a tendency for the maximum corrosion of the tin member of the couple to occur between pH 4 and 5, but the progressive admission of air to the system produced a gradual transition from a condition in which the corrosion of tin was greatest at low acidity to one in which it was greatest at high acidity. The fact that tin ions (produced by corrosion of the tin) have a marked inhibiting effect on the corrosion of steel, singly or in couple, was noted by Kohman and Sanborn[12] and confirmed by Morris and Bryan[7], who showed that as little as two parts per million of tin halved the rate of corrosion of steel by a 0.5 per cent solution of citric acid at 25°C. Other compounds whose inhibiting action on steel corrosion was studied by Morris and Bryan[7] included a number of colloids such as gelatin, pectin etc., and sugars of commercial quality; a number of their results are summarised graphically in Fig. 25. Sugar itself was
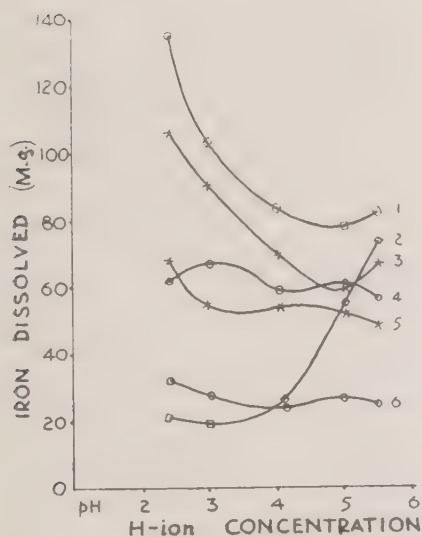

FIG. 25. The effect of hydrogen-ion concentration on the efficiency of various inhibitors of the corrosion of iron.

1. Standard curve for the corrosion of iron by solutions containing 5 grms. of citric acid per litre buffered over the pH range with sodium citrate.
2. Curve with similar solutions +0.5 per cent of gelatine.
3. Curve with similar solutions +0.5 per cent of pectin.
4. Curve with similar solutions +4 parts per million of tin as citrate.
5. Curve with similar solutions +25 per cent of sucrose.
6. Curve with similar solutions +25 per cent of brown beet sugar.

The period of corrosion was three days in each case, except No. 6 which was nine days. All the curves except No 3 depart more from the normal at high than at low acidity.

(Courtesy Controller H.M. Stationery Office)

found to be only a weak inhibitor, but commercial sugars (especially beet sugar) contained traces of powerful inhibiting substances. Some of the inhibitors studied, especially gelatin, became considerably less effective as the acidity was reduced, but the unidentified inhibitor present in beet sugar was relatively little affected by pH.

The effect of sulphur, either as sulphur dioxide or as hydrogen sulphide, in accelerating the corrosion of cans has been studied by Clough, Shostrum and Clark[13,14]. Sulphur often occurs (probably as sulphite) to the extent of a few parts per million in the more refined

grades of sugar, which have been bleached or had substances such as ultramarine added to improve the colour. The permitted maximum content of sulphur is 70 parts per million, but various workers have shown that as little as 10-20 parts per million accelerates the corrosion of steel in solutions more acid than pH 4.5 (see below). Another possible source of sulphur, which has been investigated by Culpepper and Moon[15], is the use of sprays or powders during cultivation of the fruit, and all such contamination should be removed before the fruit is packed.

The accelerating effect on corrosion, of oxygen enclosed within the can, has been demonstrated in practical canning tests by Kohman[16], while Culpepper and Caldwell[17] have shown the importance of reducible substances, such as the anthocyanin pigments of certain highly coloured fruits, which may be furnished by the pack itself. These substances act as depolarising agents for the cathodic reaction, and so promote corrosion. Perforations are particularly prevalent in the highly coloured fruits, which are usually packed in lacquered cans to preserve the colour.

The influence of the composition of steel on the rate at which it is attacked by acid media has been studied by many investigators, including Morris and Bryan[11] and especially Hoar and Havenhand[18], whose work has thrown considerable light on the mode of action of certain accelerators and inhibitors which are important in canning. Hoar and Havenhand[18] were able to show that in most of an extensive range of steel samples corroding at widely varying rates the efficiency of the cathodic process was practically the same, so that differences in corrosion rate were due to differences in polarisability of the anodic areas. The corrosion media used (in contact with air) were citric acid and citrate buffer solutions, with or without various additions such as sulphur compounds or tin ions. Dissolved sulphur, either as sulphur dioxide or as hydrogen sulphide (to which sulphur dioxide would be reduced in contact with the corroding iron), invariably lowered the corrosion potential and hence must reduce the anodic polarisation, but it also had an inhibiting effect on cathodic depolarisation by oxygen. The nett result was therefore the balance of these two effects. In strongly acid solutions the cathodic reaction was predominantly hydrogen evolution and sulphur acted as an accelerator, but with increase in pH the depolarising action of oxygen became increasingly important, and at pH 4.89 the accelerating action of sulphur was negligible. Hydrogen sulphide produced by dissolution of any sulphide within the steel must clearly have the same effect, and in harmony with this it was found that the corrosion of "slow steels," presumably producing little hydrogen sulphide on their own account, was accelerated by added sulphur much more than that of

"fast" steels which were already corroding rapidly by virtue of their sulphur content. The effect of tin ions in retarding the corrosion of steel was confirmed by Hoar and Havenhand[18], who found that the effect was on the anodic reaction and was most marked under conditions where sulphur exerted its greatest accelerating effect. It was therefore concluded that tin ions served to remove hydrogen sulphide as insoluble tin sulphide, a simple explanation which was supported by the observation that ions of other metals, e.g. cadmium, were similarly effective if their sulphides were insoluble in the corrosion medium. A more effective corrosion inhibitor was copper in the steel, this also probably acting by the removal of sulphide. The occurrence of inclusions of massive cementite in the metal was found to stimulate the cathodic reaction. As the result of their investigation, Hoar and Havenhand[18] recommended that the steel base for tinplate to be used in canning should have :—

(1) A low sulphur content, especially in the surface layers ; rimming steels would appear to offer some advantage.
(2) A copper content not less than twice that of sulphur.
(3) Freedom from massive cementite.

The question of the most desirable composition of the steel base has also been discussed by Hoar, Morris and Adam[19], who suggest for pack-rolled plate a copper content of from 0.16 to 0.22 per cent and a phosphorus content below 0.04 per cent, while Hartwell[20] considers that the detrimental effects of copper outweigh its advantages, and suggests for cold-rolled plate a copper content of 0.06 per cent and a phosphorus content of 0.015 per cent. According to Macnaughton[21], the cold-rolling process permits the use of steel of higher purity, particularly as regards the phosphorus content, and also produces a finer and more uniform grain structure than has hitherto been possible. With the facility afforded by the cold-rolling process, of working to closer limits in the composition of the steel base, it should be possible eventually for the can maker to specify a particular composition of plate to suit the type of product for which the cans are intended. As a convenient means of evaluating the corrosion resistance of various types of tinplate, the hydrogen evolution test of Vaurio, Clark and Lueck[22], already described in Chapter 2, may be used. A can end stamped from the sample of tinplate to be tested is subjected to the action of dilute hydrochloric acid under carefully controlled conditions, and the time taken for the evolution of five cubic centimetres of hydrogen is taken as an index of the corrosion resistance. The results so far obtained by this method have been found to correlate with those obtained in actual canning practice.

It has been pointed out by Hoar, Morris and Adam[19] that a can end stamped from untinned steel base should be used for evaluating the corrosion resistance of lacquered plate, and they also suggest that the corrosion testing of tinplate should take into account the properties of the interior of the steel as well as of the surface layers, since the latter may not give a true picture of the tinplate as as whole, particularly as regards its ability to resist the development of perforations.

To summarise, the following factors are important in the corrosion of tinplate under the acid conditions typical of those encountered in fruit packs :—

(1) The fact that tin is usually anodic to steel in such packs, thereby affording electrochemical as well as mechanical protection to the steel base.

(2) The inhibiting effect of traces of tin salts or collodial materials present in the pack, or of copper present in the metal, on the corrosion of steel.

(3) The accelerating effect of certain substances, particularly traces of sulphur compounds derived from the pack or from the steel itself, on the corrosion of steel.

(4) The accelerating effect of oxidising agents or of oxygen, particularly on the corrosion of tin, which makes it essential, therefore, to eliminate the maximum amount of oxygen by efficient exhausting and sealing.

From what has been said, it will be seen that in any given pack the corrosion behaviour is the resultant of many diverse factors, and unexpected phenomena are often found. Thus, although in simple solutions corrosion increases with the acidity, it is not usually the most acid fruits which are most troublesome, and the *addition* of citric acid may be beneficial. (Hoar[8] suggests that this is partly due to the greater effectiveness of natural inhibitors, present in the fruit, at higher acidities.) In general, however, it may be said that the theory of corrosion outlined above is capable of interpreting practical results and of indicating remedies, once the individual characteristics of the system are known.

The development of hydrogen swells and perforations. The incidence of hydrogen swells and perforations is chiefly confined to the fruit and vegetable canning industry, and is sometimes responsible for considerable loss and spoilage.

Cans for these packs may be either plain tinplate or coated with one or more thin films of lacquer, the choice of can being determined by the product to be packed. Plain cans are usually used for the packing of fruits with little, or relatively stable, colouring matter such as peaches, pears, etc. ; the more highly coloured fruits such as cherries,

raspberries, loganberries, etc., are, however, frequently packed in lacquered cans. Lacquered cans are also used where sulphur staining is likely to occur, a phenomenon referred to later in this chapter.

The presence of the lacquer film and the accelerating action of the highly coloured fruits usually packed in this type of can make the problems associated with the lacquered can somewhat different from those appertaining to the plain can and they must, therefore, be considered separately.

As indicated above, in the plain can corrosion tends to occur by the gradual solution of the tin coating over wide areas and the simultaneous deposition of hydrogen at the bare areas of steel, with some local action at the steel itself. The steel base in a plain can receives the maximum amount of electrolytic protection, since the entire tin coating is available to act as the anode. In the plain can, also, the amount of tin going into solution is greater than in the lacquered can and there are, therefore, more tin ions in solution to act as inhibitors of corrosion.

In the lacquered can, the lacquer film covers both the steel base and also the tin coating, but the fabrication of the lacquered sheet damages the lacquer film and may also fracture the tin coating, particularly at the side seam and the shoulder of the can end. At these points, therefore, corrosion is likely to occur, although Hirst and Adam[23] have shown that the majority of the corrosion takes place at the side seam rather than at the can end.

As the tin surface is covered with lacquer, except at the points damaged during fabrication, there is little tin available for electrolytic protection of the steel base and the attack tends to be concentrated on this member of the couple rather than on the tin coating as is the case with the plain can. The behaviour of plain and lacquered cans has been studied by Adam[24] whose results, Table IV, show that there is a very considerable difference in the shelf life to be expected from lacquered as compared with plain cans.

TABLE IV
Effect of Lacquering Cans Stored at 95 F.
(*Adam*)

Fruit	Period to reach 25 per cent loss	
	Plain cans Weeks	Lacquered cans Weeks
Gooseberries	46	24
Cherries	19	18
Greengages	34	23
Golden plums	61	24

The inferior performance of lacquered cans has resulted in efforts being made to improve the lacquer film, but the fundamental difficulty is that, although a perfect film might be obtained on the flat sheet, fabrication inevitably causes damage. The problem has, therefore, been attacked from another angle and attempts made to lacquer the cans after fabrication. Spray-lacquered cans as shown by Adam[24] in Table V have a greatly increased storage life, and further work by Hirst and Adam[23] demonstrated that the life of these cans might be expected to be three times that of cans lacquered in the normal manner. The same authors[23] stored spray-lacquered cans at 95°F. in order to accelerate the rate of corrosion, and they state that if the same results are obtained at normal temperatures, and there is no reason to suppose otherwise, the marketable life of spray-lacquered cans should be prolonged for three or four years and the incidence of hydrogen swells will be of no greater magnitude than that experienced with canned vegetables at the present time.

TABLE V

Effect of Protecting Seams by Spray Lacquering, Cans Stored at 95°F.

(*Adam*)

Fruit	Period to reach 25 per cent loss	
	Standard Method Weeks	Spray Lacquered Weeks
Gooseberries	38	105
Loganberries	25	120
Cherries	24	76
Blackcurrants	26	57
Pershore plums	71	123
Greengages	42	90

It will be seen, therefore, that there is a strong case for packing fruit in cans lacquered after fabrication. Initially, the cost of the post-lacquered cans may be greater than that of the normal type, but this increase must be offset against the decrease in losses due to corrosion and, in the case of highly pigmented fruits, the elimination of the risk of discoloration which is liable to occur in cans where the lacquer coating is damaged and the metal surface exposed. The damage caused in fabrication has also been studied by Kohman[25], who has shown that scratches on can lids and rough surfaces within the can all contribute to increased corrosion.

The various methods used in lacquering sheets and cans are described in Chapter 4.

The practice of embossing an identification code on can ends is another source of damage to the tin coating, and Cheftel[26] has used the ferricyanide test to show that the tin surface is fractured and the steel base exposed if the embossing is made too deep. Printing the code in ink or by some other means such as the electrolytic method patented by Clayton and Sumner[27], or the chemical method of Barlow et al.[28], is greatly to be preferred, especially with acid fruits.

As already mentioned, the rate of corrosion increases with rise in temperature and it is, therefore, to be expected that the incidence of hydrogen swells and perforations will tend to increase if the filled cans are stored at high temperatures. This problem has been fully investigated by Kohman and Sanborn[29], who found that the rate of loss both from hydrogen swells and perforations increased considerably when the cans were stored at the elevated temperatures likely to be encountered in warehouses during the summer months. They also found that storage at 32°F. greatly prolonged the life of all types of canned fruits and, in addition, preserved their natural colour; loganberries and strawberries after two and one half years' storage at 32°F. had practically the appearance of the freshly canned berries. Fig. 26 shows the increase in losses due to hydrogen swells and perforations in loganberries when stored at an elevated temperature.
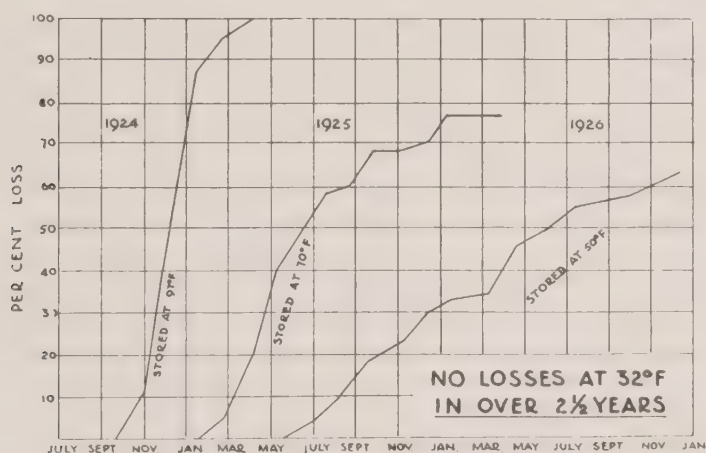
Fig. 26. Losses from hydrogen swells and perforations in canned loganberries stored at 32°, 50°, 70° and 97°F., respectively.

(Courtesy National Canners Association)

It was also observed that there was a greater tendency to form hydrogen swells rather than perforations at the higher temperatures.

The fact that high-temperature storage tends to increase the rate of corrosion indicates that the efficiency of cooling after processing will also play a part in the reduction of hydrogen swells and perforations.

Cooling should, therefore, be as rapid as possible with products liable to hydrogen swells.

The formation of hydrogen swells and perforations is controlled by many factors, and for the sake of clarity the main points are summarised below :

(1) The presence of excessive amounts of oxygen accelerates the rate of corrosion of both the tin coating and the steel base.

(2) Fruits with a pH value of about 4.0 tend to corrode more quickly than the more acid fruits.

(3) The internal lacquering, if damaged, increases the depth of corrosion as attack is concentrated on a relatively small area of the steel base.

(4) Certain substances, particularly sulphur compounds, increase the rate of corrosion.

(5) The presence of substances which absorb tin salts or act as depolarising agents increases the rate of corrosion.

(6) The composition of the steel baseplate and its method of manufacture have a considerable effect on the ultimate corrosion resistance of the finished tinplate.

(7) High-temperature storage and inefficient cooling increase the incidence of hydrogen swells.

Co-operation between the canner, can maker and tinplate producer can do a great deal to reduce losses due to hydrogen swells and perforations ; the following represent the chief steps which should be taken :

(1) Elimination of the maximum amount of oxygen by an efficient exhausting process before sealing the can.

(2) Adjustment of the acidity of low acid fruits.

(3) Use of cans lacquered after fabrication.

(4) Elimination of corrosion-accelerating substances from the raw materials used in canning ; sulphur sprays on fruit and sugar with a high sulphur dioxide content are examples.

(5) Use of cold-rolled tinplate with a low metalloid content.

(6) Storage at as low a temperature as possible 32°F. being the ideal.

(7) Rapid cooling of filled cans after processing.

Increase in the metal content of the pack, thereby rendering it unfit for consumption. A corollary to the internal corrosion of the can is the contamination of the contents with salts of tin and or iron : the greater the extent of the corrosion, the greater will be the metal content of the pack.

The question of the metal content of canned foods is more fully discussed in Chapter 10, but it can be stated here that with the improvement in canning and can-making technology the possibility of canned foods containing a harmful amount of metal is extremely remote.

Discoloration of the Interior of the Can and/or its Contents

The most prevalent form of discoloration affecting the interior of the can, and less frequently the contents, is that known as sulphur staining. This is liable to occur in certain vegetables, meat, milk and marine products. The majority of these products contain large quantities of protein which, when heated, liberate hydrogen sulphide or organic sulphur compounds containing free—SH groups. These compounds then react with the tin and iron of the tinplate to form tin and iron sulphides which are dark in colour. The amounts of metallic sulphides produced in this manner are extremely small, but the intensity of the colours is so great that it is often thought that large quantities are present and that the contents of the can are unfit for consumption. These stains, however, in no way affect the nutritional value or the palatability of the food, and are only objectionable from the aesthetic angle.
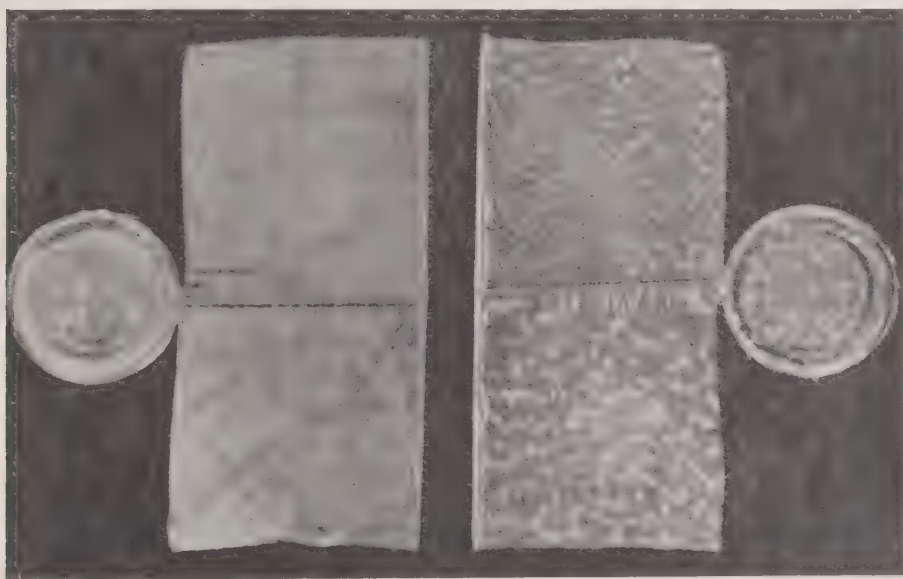

Fig. 27. Sulphur staining on the interior of two cans packed with the same product and fabricated from sheets of tinplate drawn from the same box.

The most common type of staining affects the interior surface of the can and not the contents : the appearance of this type of stain is shown in Fig. 27 and it will be seen that the stains follow definite

patterns due to the preferential staining of the tin surface, some crystal faces staining more readily than others. On closer examination it will be seen that at the side seam of the can, where heat has been applied during the soldering operation, the stained areas are small and acicular in shape extending at right angles to the side seam ; this is due to the recrystallisation and reorientation of the crystals composing the tin surface during the soldering operation. The feathery stain due to tin sulphide is often blue or purple in colour, but the more heavily stained areas tend to be brownish black.

The degree of staining varies considerably, tinplate from some sources staining more heavily than that from other sources ; there may even be a variation from sheet to sheet and Fig. 27 illustrates this phenomenon, the two cans being filled with the same product and processed under the same conditions. Sumner[30] found that such variations were attributable to differences in the protective value of the oxide films on the various tinplates (See Chapter 4).

The intensity of staining also varies from product to product, depending on the protein sulphur content of the food and the ease with which sulphur compounds are liberated. A further controlling factor is the acidity of the can contents, and it is rare to find sulphur stains occurring in products with a pH value of less than 5.5–6.0.

The presence of oxygen is also an important factor ; Gire[31], for example, has studied the effect of solutions of sodium sulphide on the surface of tinplate, and has demonstrated that oxygen is indispensable for the attack.

The prevention of sulphur staining is, fortunately, a relatively simple matter. A special sulphur-resisting lacquer having been developed by Bohart[32], after Fitzgerald, Bohart and Kohman[33] had shown that zinc salts prevented the discoloration of canned corn. This lacquer contains a small proportion of zinc oxide, which reacts with the sulphur compounds liberated during processing to form zinc sulphide, which is white in colour and, in the quantities present, in the lacquer is only visible as a pearly sheen. More recently, new methods of forming protective oxide films on tinplate have been developed and used experimentally for the prevention of sulphur staining ; these methods, more fully described in Chapter 4, can be applied either to the flat sheet or to the fabricated can, and Fig. 28, after Kerr[34], shows how effective the method can be with meat packs which have a nearly neutral reaction. These films give very good protection in the less acid packs, but tend to break down as the pH value of the can contents decreases.

The formation of tin sulphide is not a particularly serious matter and it has even been used as a preventative of further corrosion by Bogatsky, Biber and Kischinewskaja[35]. Iron sulphide on the other

hand, especially when due to the natural sulphur content of the food, is very difficult to control and may pass into the can contents and so affect the appearance that the product is unsaleable. In the U.S.A. the high degree of loss of canned corn through discoloration due to iron sulphide caused Fitzgerald, Bohart and Kohman[33] to make an intensive study of the causes of this phenomenon, the result of which was the development of the sulphur-resisting or C-enamel, to which reference has already been made.

A black flaky deposit is sometimes observed in canned peas, but in general any stains are confined to the tin surface and do not penetrate the contents of the can.

FIG. 28. Cans illustrating the effect of phosphate-chromate treatment on sulphur staining. Untreated can (left), and treated can (right). Both cans were packed with mutton broth and stored for one month at 37°C., and four months at room temperature.
(*Courtesy Tin Research Institute*)

The problem of staining in canned fruits is not of very great importance for, as already stated, staining does not often occur at low pH values. Morris and Bryan[11] have, however, mentioned the occurrence of staining in canned apricots, and Cruess[36] states that some loss has been incurred through the formation of black deposits in canned fruits due to the use of sugar containing sulphur dioxide.

In meat and meat products, which are usually high in protein or protein-like substances and have a relatively high pH value, sulphur staining invariably occurs, and it is common practice to use internally lacquered cans if staining is to be avoided.

With marine products the problem is more difficult, as discoloration of the product is a not uncommon occurrence, particularly with shrimp, crab and lobster. The effect of the condition of the product at the time of death and the time elapsing between capture and canning has been studied by Harrison and Hood[37], who showed that increase in the time of storage before canning increases the tendency to blacken and that blackening varies with the season of the year at which the product is caught. The decrease in blackening with decrease in pH value suggested that adjustment of acidity might yield promising results, and it has been shown by Dill and Clark[38] that at values lower than about pH 6.5 blackening of marine products does not occur, while Legendre[39] and Oshima[40] have studied in detail the artificial modification of the pH value by the addition of citric acid, lemon juice or vinegar to those products where the flavour can stand such additions. It is now the practice to use acid blanches or washes for this purpose. Further precautions are the use of sulphur-resisting lacquer and the lining of the cans with parchment paper.

Milk and milk products are not in general subject to sulphur staining, but Jackson, Howat and Hoar[41] have observed that the following defects may occur in canned cream after some months' storage :—

(1) "Purpling" of the can due to the formation of a film of tin sulphide.
(2) Pitting of the surface of the container.
(3) Formation of black patches and of black specks in the body of the cream, consisting of ferrous sulphide or stannous oxide or both.

They state that purpling is produced by excessive time and temperature of sterilisation and that the addition of up to 5.0 grms. per gallon of sodium bicarbonate, as is the common practice to stabilise the cream, has if anything a slightly beneficial effect with respect to the development of purpling.

Experiments conducted with cans in which large areas of steel were deliberately exposed demonstrated that a non-adherent film of black iron sulphide was formed, which on storage became distributed through the body of the cream.

Although fruits are not as a general rule affected by sulphur staining, certain varieties are liable to discoloration by the tin and iron salts which may be present in the can as a result of corrosion.

The colouring matter of fruits and vegetables may be divided into two classes, the first and most important being the anthocyanin pigments which occur in the blue, purple and red fruits, while in the second class are the carotenoids found, for example, in carrots and tomatoes.

The anthocyanin pigments are sensitive to small quantities of tin, and an extensive study of their behaviour during canning has been made by Culpepper and Caldwell[42]. The red or dark purple colour is changed to a pale mauve in the presence of tin salts. As little as 10 p.p.m. of tin in blackcurrants was stated by Morris and Bryan[11] to be objectionable, while with strawberries up to 100 p.p.m. could be tolerated. On the other hand, 2 p.p.m. of iron were sufficient to produce discoloration in strawberries, while with blackcurrants even 80 p.p.m. of iron only produced a slight discoloration. This is explained by the fact that blackcurrants represent a class of fruit rich in anthocyanin pigments which are only very slightly affected by iron salts ; strawberries, however, contain only a small proportion of anthocyanins and are not, therefore, greatly affected by tin salts, but they contain tannins and allied substances and these are acted on by iron salts, causing a darkening of the fruit. The same effect has been demonstrated with sweet potatoes by Kohman[43], who has stated that the iron must be in the ferric state to cause discoloration.

The reducing or bleaching action of tin salts is made use of according to McKenzie[44] by packing in plain cans such products as pears, pineapples and grapefruit where it is desirable to maintain a bright natural colour.

The problem of discoloration is overcome by the use of lacquered cans, thus limiting the amount of tin and iron salts in solution.

External Corrosion of the Container

Although the internal condition of the pack is of primary importance, corrosion of the exterior surface of the can must be taken into account, as in addition to the unsightly appearance of the container, severe external corrosion may lead to losses through perforation of the can.

In most examples of external corrosion, the tin coating is cathodic to exposed steel and the latter corrodes preferentially, leading eventually to the formation of rust at discontinuities in the coating.

The possibility of external corrosion exists from the moment the cans leave the can-making machines. Rust formation will almost certainly result from poor storage conditions ; the presence of leaky roofs and windows in can stores is but one example of a likely source of rust formation. Rusting may also occur even in the best possible storage conditions if there is any possibility of moisture

condensing on the stored cans from steam escaping in the vicinity of the empty can store. The ideal empty can store is a warm dry warehouse where there is good air circulation and sufficient space to make frequent inspection of stocks possible.

Can ends are usually sent from the can-making plant in cylindrical paper sleeves which, if they become damp, can be a frequent source of rusty can ends. It is particularly important to ensure that can ends are not kept in the vicinity of the closing machine in such a position that they may become contaminated by spillage of brine, fruit juices or water.

The type of product being packed may well affect the external as well as the internal corrosion of the can : the packing of acid fruits and of products packed in brine, even under the most carefully controlled conditions, cannot be accomplished without some degree of spillage, and the exterior surface of the can is, therefore, constantly exposed to the possibility of corrosion caused by contamination from this source. With acid fruits which only require processing at the boiling point of water, the fruit acid on the exterior of the can is being constantly transferred to the processing and cooling tanks, with the result that the acidity of the processing and cooling water is constantly increasing and conditions very conducive to corrosion develop. If, as in the case of certain vegetables, brine is used for packing, the increase in salt content of the cooling water may also lead to the same result. Cans containing products which require high-temperature processing should be thoroughly cleaned before placing in the retorts as any dirt, meat residues, etc. on the exterior surface of the can are liable to become baked on during processing, after which they are extremely difficult to remove, and may lead to corrosion in storage. Fortunately the method of dealing with this problem is fairly simple, as all that is required is an efficient can-washing machine installed immediately following the closing machine, as described in Chapter 9. In this connection care should be taken to avoid the use of detergents which will cause etching of the tinplate or "feathering" as it is often called. This phenomenon, although not necessarily detrimental from the corrosion angle, lends an unsightly appearance to the can and a loss in sales appeal.

There are several types of corrosion which may occur when the cans are processed ; one of the most common is due to the action of waters containing dissolved solids, this being especially true where the cans are processed in an open tank or under pressure in water. Alkaline waters will produce the "feathering" effect to which reference has already been made ; the pattern so produced follows the boundaries of the tin crystals in the tin coating, some crystal faces being more readily attacked than others.

The importance of the proper venting of retorts has been emphasised many times in connection with under-processing ; air pockets within the retort prevent even circulation of the steam and thus cause uneven heat distribution. The presence of air mixed with steam at an elevated temperature also provides ideal conditions for the rapid development of rust on the outer surface of the can. In addition an irridescent oxide layer may be formed, thereby detracting from the appearance of the can by dulling the brightness of the tinplate. These conditions may be easily corrected by the proper venting of retorts during the coming-up period and the provision of bleeder valves which are allowed to remain open during the processing period.

It will sometimes be observed that cans, on removal from the retorts, are coated with a loosely adherent layer of rust which, if allowed to dry by the heat of the can, may be difficult to remove without wiping the cans individually. This is caused by allowing the interior of the retorts to become unduly rusty, and is easily corrected by the occasional use of a wire brush on the interior of the retort.

The cooling process, however it is carried out, may be a source of can corrosion, as many natural waters containing appreciable quantities of chlorides and sulphates are particularly corrosive to tinplate. The higher the temperature of the cooling water, the more rapid will be the attack : the effect of corrosive waters may be reduced, therefore, by making the cooling process as rapid as possible by using water well below the temperature of the cans.

The evaporation of surface moisture after cooling often results in the formation of patches of solid material consisting of any dissolved solids the water may contain ; these patches are sometimes hygroscopic and lead to corrosion by absorbing moisture from the air, even when the cans appear initially to be quite dry.

Gross over-chlorination of the cooling water may also be a cause of corrosion, and it is essential for this reason alone, apart from any bacteriological considerations, to keep a close and constant check on the residual chlorine content of the cooling water.

Insufficient washing of the cans after the use of a detergent solution for the removal of grease etc. may leave sufficient residue to cause etching of the cans, and it is important to ensure that washing after cleaning in detergent solution removes all traces of the detergent.

The type of corrosion most likely to be experienced occurs in the warehouse due to the presence of excessive moisture. The most frequent cause of this is the phenomenon of "sweating" or condensation of moisture on the surface of the can, due to the can and its contents being at a lower temperature than the surrounding atmosphere. The prevention of "sweating" resolves itself into the

maintenance of an even temperature in the warehouse and arranging that there is a good air circulation round the stacks of cans or cases.

Another frequent cause of trouble is the casing of cans which are too damp or too cold. The dangers of casing at too high a temperature have often been emphasised in relation to the possibility of the development of thermophilic organisms and increased internal corrosion, and it is usual to recommend that cans which may be subject to such spoilage are cased at temperatures not exceeding 80-90°F. On the other hand, if the cans are cooled much below this temperature range there will not be sufficient heat in the cans to dry off any surface moisture and the cans may remain damp for some time, especially if they are cased in fibreboard containers. Rusting usually commences at the side and end seams, where the tinplate has been subjected to the greatest mechanical strain during fabrication ; care should be exercised, therefore, to maintain sufficient heat in the cans to dry off all surface moisture before casing. The use of corrosive label adhesives is another potential source of trouble, and all adhesives should be examined with particular reference to their alkalinity or acidity. The use of certain types of paste may facilitate the growth of moulds if a preservative is not included.

When packing in wooden cases it is essential to use only fully seasoned timber for the manufacture of the cases, as the use of unseasoned or "green" timber will almost certainly result in rusting of the cans.

Reference has been made in some detail in Chapter 4 to the method of preventing sulphur staining developed by Kerr[34]; this process has also been found very effective in protecting the exterior surface of cans against rusting. The process is exactly the same as that adopted for the prevention of sulphur staining, and can be carried out on the flat tinplate sheet before fabrication, in which case both tinplate surfaces will be treated, or alternatively the filled cans may be treated by substituting Kerr's solution for the normal detergent in the can-washing machine. If this is done it is advisable to avoid waste of solution by fitting a pump to recirculate the solution in the washing machine. Fig. 29 illustrates the remarkable degree of protection conferred on cans treated by this method.

The protection of cans for export presents a special problem, and it is usual to apply a coating of lacquer on the outside of the container by one or other of the methods described in Chapter 4. The introduction of synthetic resins has enabled considerable progress to be made in the formulation of protective coatings, and those now produced give a high degree of protection, particularly if combined with Kerr's treatment.

Fig. 29. Prevention of external rusting by chemical treatment. Both cans have been exposed for several weeks on a factory roof in an industrial atmosphere, the treated can (left) shows little signs of rust while the untreated can (right) is severely rusted.

From the above survey it will be seen that the problems associated with the external corrosion of cans are many and varied, and if clean and bright cans are to be obtained, particular attention should be paid to avoiding the following faults in procedure :—

(1) Damp and/or ill-ventilated warehouses for the storage of empty or filled cans.

(2) Improperly vented retorts which will contain pockets of air and steam and thus provide conditions favourable to corrosion.

(3) Use of low-pressure steam combined with a long coming-up time.

(4) Cooling to temperatures below 80-90°F., when surplus moisture will not evaporate.

(5) The use of wooden cases made from "green" or damp timber.

(6) Use of processing or cooling water containing quantities of dissolved substances which will corrode or leave a hard residue on the surface of the can.

(7) The use of unsuitable label adhesives which may be too acid, alkaline, or hygroscopic.

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CHAPTER 4

CAN MANUFACTURE

THE beginning of the twentieth century marks an important step in the development of the canning industry as it was about this time that the Ams brothers succeeded in perfecting the open top or sanitary type can.

Cans used at the present time may be divided into the following classes :—

(1) The open top can with double seamed ends and lock and soldered side seam.
(2) The fully soldered can with lock side seam.
(3) The deep drawn can in which the bottom and body are formed from one sheet of metal.

Cans in the first class form by far the largest proportion of the can makers' output, and are used for all classes of products.

The second group includes cans used for such products as milk, corned beef etc., where the contents may be filled through a small aperture in the lid which is then closed with a spot of solder or by a small disc of tinplate soldered on the lid after filling. In the third group are cans used for such products as fish, fish and meat pastes, etc.

One of the few useful results of the war has been the standardisation of can sizes by the British Standards Institution with the co-operation of the can makers and the canners, and it is to be hoped that there will be no return to pre-war conditions when the number of different can sizes was legion and resulted in much waste of tinplate and labour. Space does not permit the inclusion of all the different can sizes included in the British Standards schedule[1], but Table VI shows those

TABLE VI

Round Open Top Cans in Common Use

Description	Dimensions Diameter Height	Nominal Capacity Fluid ounces
A.1	211 × 400	11.0/11.1
A.1.T.	301 × 411	16.8/16.9
A.2	307 × 408	20.2/20.4
A.2½	401 × 411	29.7/29.9
A.10	603 × 700	108.5/109.2

most used and also the method of designating each size. In describing a can it is customary for the can maker to quote the diameter first. followed by the height, the first digit in each group of figures representing inches and the second and third digits sixteenths of an inch: thus 301 x 411 indicates that the diameter is $3\frac{1}{16}$ inches and the height $4\frac{11}{16}$ inches.
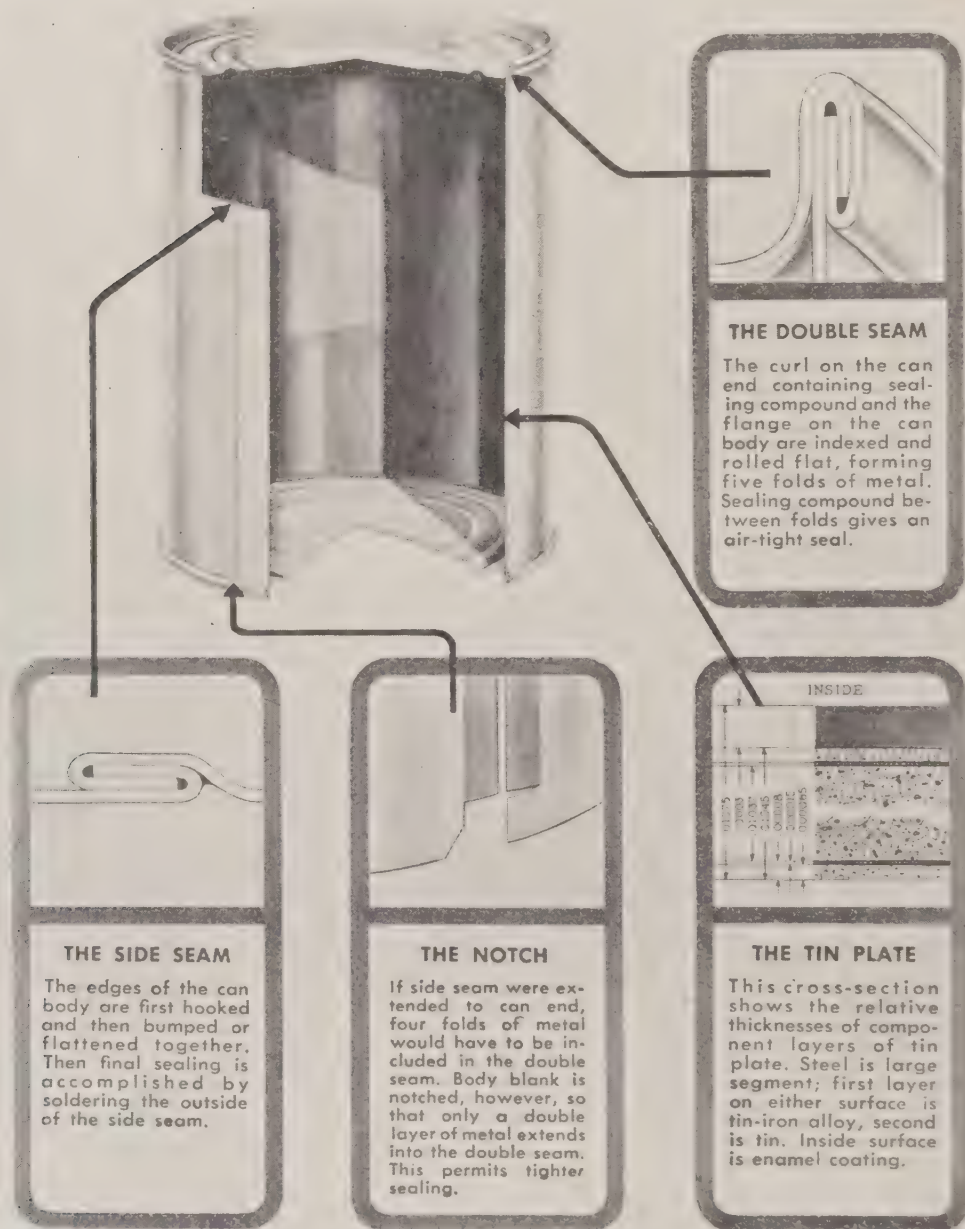

THE DOUBLE SEAM

The curl on the can end containing sealing compound and the flange on the can body are indexed and rolled flat, forming five folds of metal. Sealing compound between folds gives an air-tight seal.

THE SIDE SEAM

The edges of the can body are first hooked and then bumped or flattened together. Then final sealing is accomplished by soldering the outside of the side seam.

THE NOTCH

If side seam were extended to can end, four folds of metal would have to be included in the double seam. Body blank is notched, however, so that only a double layer of metal extends into the double seam. This permits tighter sealing.

THE TIN PLATE

This cross-section shows the relative thicknesses of component layers of tin plate. Steel is large segment; first layer on either surface is tin-iron alloy, second is tin. Inside surface is enamel coating.

FIG. 30. The structure of the modern open top or sanitary can with enlarged diagrams of its component parts.

(Courtesy American Can Co.)

The Open Top Can

Before considering the manufacture of cans in detail it is well that the reader should appreciate the essential elements in their construction. The modern open top can consists of three parts : a body and two ends, one end being double seamed to the body by the can maker and referred to as the maker's end, and the other end being supplied loose and seamed on by the canner and referred to as the canner's end.

A completed can and the relationship and construction of the various components is shown in Fig. 30. The relation of can body to can end before the seaming operation is commenced, and the relative position of the curl on the can end and the flange on the can body is shown in Fig. 31. Various stages in the seaming operation are shown in Fig. 32. The sealing compound acts as a cushion between the layers
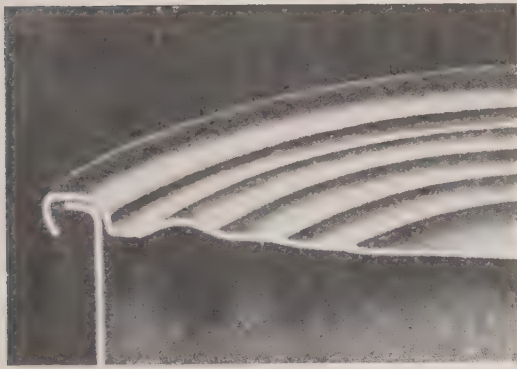

FIG. 31. Can body and end before seaming commences.
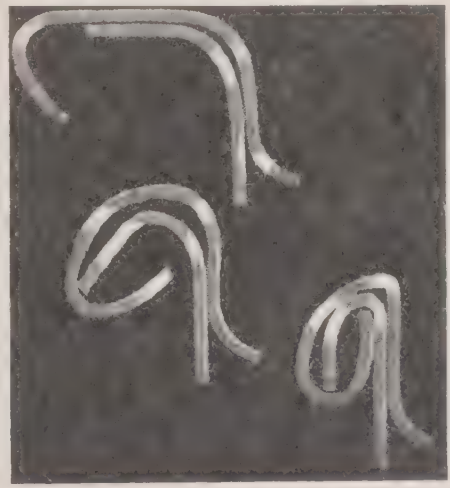*(Courtesy American Can Co.)*

FIG. 32. Stages in the seaming operation.
(Courtesy American Can Co.)

of tinplate and fills any slight discontinuities which may develop during the seaming operation. Fig. 33 illustrates the relationship between end and body after the seaming operation. A more detailed consideration of the seaming operation is included in Chapter 8.

The various machines which form the can-making line are,

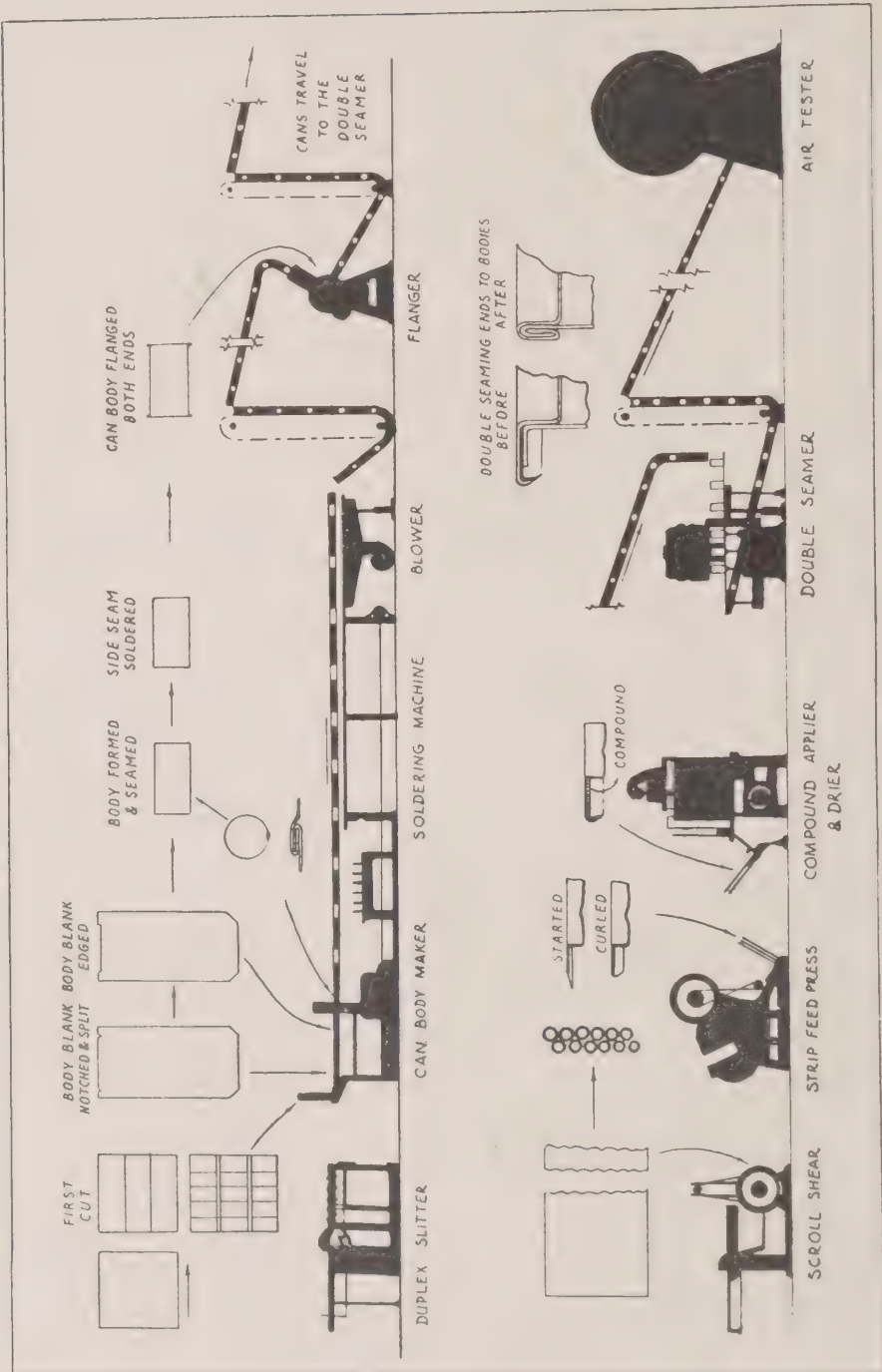FIG. 33. The completed double seam.
(Courtesy American Can Co.)

Fig. 34. Flow sheets showing the various stages in the manufacture of round open top can bodies and ends.

(Courtesy E. W. Bliss Co.)

for the most part, entirely automatic, being provided with electric warning devices which give the alarm when a stoppage occurs.

A flow sheet illustrating the various operations is shown in Fig. 34 and it will be seen that the process consists of the following steps :—

(1) Cutting body blanks.
(2) Forming the side seam.
(3) Soldering the side seam.
(4) Flanging the ends of the body.
(5) Double seaming the bottom end.
(6) Air-testing the finished can.

In addition to the above an auxiliary line of machinery is required to maintain the supply of ends, the operations of this line being as follows :—

(1) Cutting strips of tinplate with scroll shears.
(2) Stamping the end and curling the periphery.
(3) Applying and drying the lining compound.

A large number of the cans used today are lacquered internally and this additional operation will be considered later in this Chapter.

The Manufacture of Can Bodies.   Sheets of tinplate as received from the tinplate maker are first inspected to ensure that they are free from defects, although when using automatic sheet feeding machines only a cursory inspection of the whole bundle is given.

The sheets are cut by means of automatic slitters of the type shown in Fig. 35. The cutters are of "T" section and mounted on adjustable hubs, which can be moved along the main shaft to suit the width of strip to be cut. If the machine is a single slitter two are coupled in tandem, one cutting in one direction and the other at right angles. Duplex slitters in which the two operations are carried out by one unit are now much used. Automatic feeds can also be obtained, and when these are used the operator need only load a box of tinplate on to the feeding station and unload the cut body blanks at the other end of the machine. Speeds of up to 700 blanks per minute are attained with Duplex slitters.

The cutting of body blanks is an extremely important operation. and endless trouble will be caused if the blanks are not cut absolutely true and square. Body blanks are cut with the direction of rolling or the grain of the plate coinciding with the length of the blanks so that subsequent bending will be across the grain.
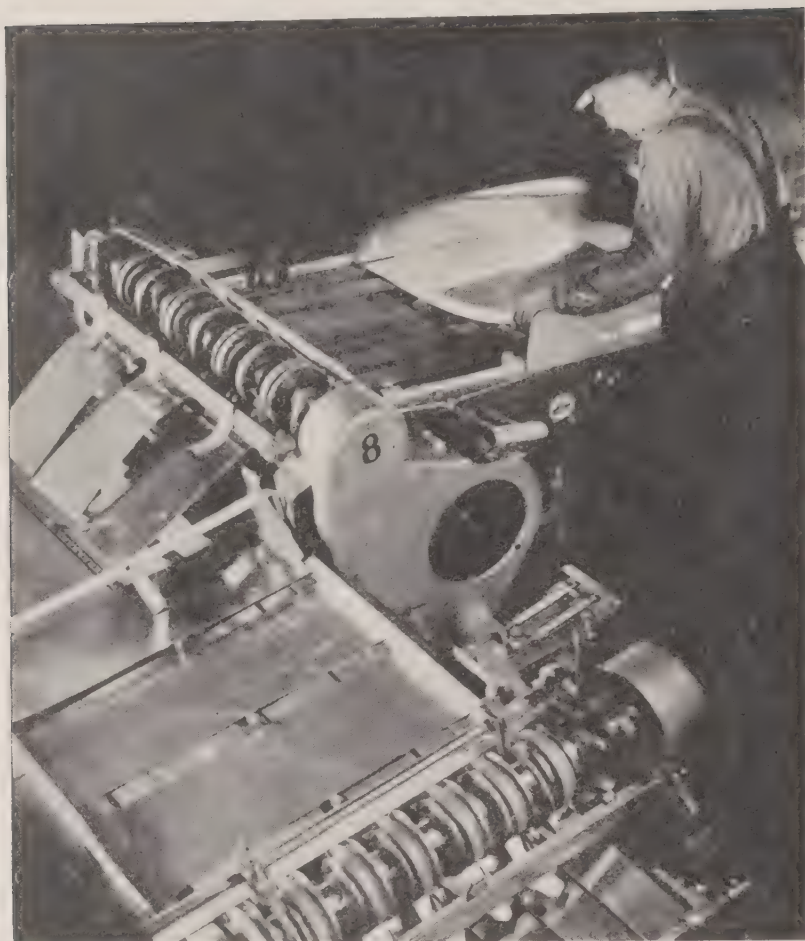
FIG. 35.   Slitting tinplate sheets for can body blanks.
(Courtesy American Can Co.)

After cutting, blanks are loaded into the magazine of the body
maker from which they are automatically fed by means of a rubber
vacuum cup, the vacuum being broken immediately the blank is
picked up by the reciprocating feed bars in the bed of the machine.
A flexing attachment is very often incorporated in the body maker at
this point to remove irregularities in the blank and ensure a perfectly
cylindrical can body.   This operation is particularly necessary to
avoid fluting or panelling of the body if light-weight tinplate is being
used.   The flexed blanks then pass to the notching station where the
corners of each blank are slit and notched in the manner shown in
Fig. 36.   The importance of this operation will be appreciated if the
structure of the double seam is studied, when it will be readily seen
that without the notching operation there would be eleven thicknesses
of metal at the point where the side seam is rolled into the double
seam.   The notching operation ensures the proper hooking of the side

seam and the right degree of overlap of the short lap seam at the top and bottom ends of the side seam. After the notching operation the blanks are automatically transferred to the edging station where the edges of the blanks between the notches and slits are bent, one up and one down, to form the hooks for the lock seam as shown in Fig. 37.

From the edging station the blanks pass through a flux-applying attachment, where flux is applied to the hooks in such a manner that no flux gets inside the can. The blanks then pass to the body-forming station where they are bent into shape round an expanding mandrel or horn by means of two semi-circular oscillating wings, the two hooks engage, the horn expands and the seam is flattened by blow from a flat faced hammer. The horn has a groove along its length so positioned that the lock seam is pressed into it during the flattening
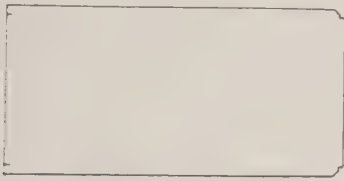
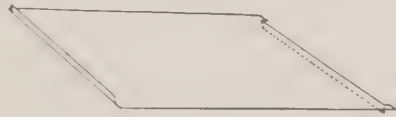Fig. 36. Slit and notched body blank.

Fig. 37. Body blank after edging.

operation, thereby producing a smooth surface on the outside of the can, the four thicknesses of metal in the seam being formed on the inside of the can as shown in Fig. 30.

The formed body is then transferred from the body maker horn to the skeleton horn of the soldering machine, where it is picked up on an endless can feeding chain and carried along to the fluxing station where a second application of flux, this time on the outside of the seam, is given. The flux is usually applied by a narrow wheel which dips into a bath of flux and then presses against the side seam as the body passes overhead. The can body then passes over revolving soldering rolls which run in a bath of molten solder, the temperature of which is usually thermostatically controlled and maintained by gas or electricity. The soldering rolls are of considerable length to ensure that the can seam is properly heated and soldered. It is essential that the solder rolls should be kept clean and bright, and this is usually accomplished by covering the molten solder with a layer of flux. After soldering the can bodies pass over a rapidly rotating rag buffing wheel, which removes surplus solder and also gives a smooth surface to the soldered seam. The excess solder is either returned to the solder bath or collected for subsequent

purification. The quantity of solder used varies with the size of can being made, but for an A2 can it averages about 1.1 lb. per 1,000 cans. After removal of excess solder the can passes through an air blast which cools and solidifies the solder.

The equipment of the body-maker, Fig. 38, includes an extensive system of electric safety controls which stop the machine in case of trouble developing in any of the body forming operations. The solder attachment, however, continues to operate, thus avoiding excessive heating of the can bodies, a point of particular importance in the case of lacquered cans.
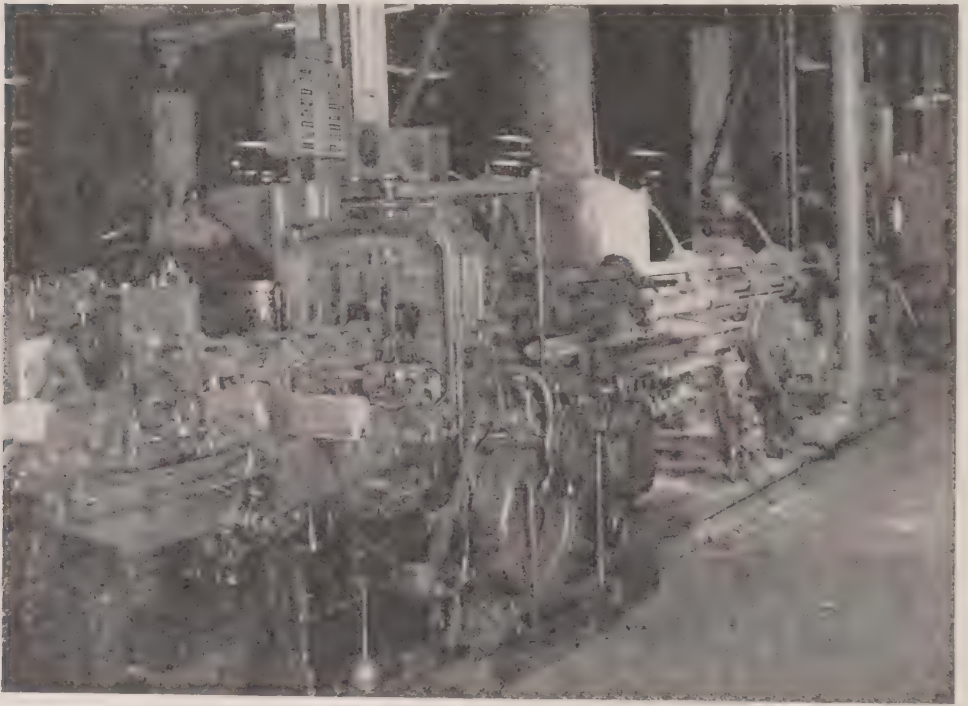

FIG. 38. Can body making unit consisting of bodymaker and side seamer.
(*Courtesy American Can Co.*)

The soldered can bodies are next conveyed up a suitable runway from which they roll by gravity to the flanging machine, or in some cases to a combined flexer and flanger if the flexing operation has not already been carried out in the body maker. Flanges are formed on both ends of the can bodies simultaneously, each flange being about $\frac{1}{8}$ in. wide. The flanging operation is carried out by a pair of flanging heads which are forced a short distance into both ends of the can body simultaneously producing a flange on each end of the can body as shown in Fig. 39.

Manufacture of Can Ends. In order to save tinplate it is customary to stamp the ends from a sheet in a staggered pattern, as shown in Fig. 40, instead of in parallel rows. By so doing up to 5 per cent saving in tinplate can be effected depending on the size of the can.

The cutting of the plate into strips is done by means of scroll shears which cut the strip into a single, double or triple row depending on the type of press used for stamping the ends. The cut strips are placed in stacks and transferred to the automatic strip feed presses, Fig. 41, which are capable of stamping up to 300 ends per minute.

Fig. 39. Can bodies entering flanger.
(*Courtesy American Can Co.*)

The strips are fed one by one into the press by rubber suction pads, picked up by a reciprocating feed bar and carried under a die which performs a combined blanking and forming operation on from one to three ends at each stroke of the press, depending whether single, double or triple dies are used. The presses are fitted with electrically actuated stop mechanisms which stop the press in the case of a jam.
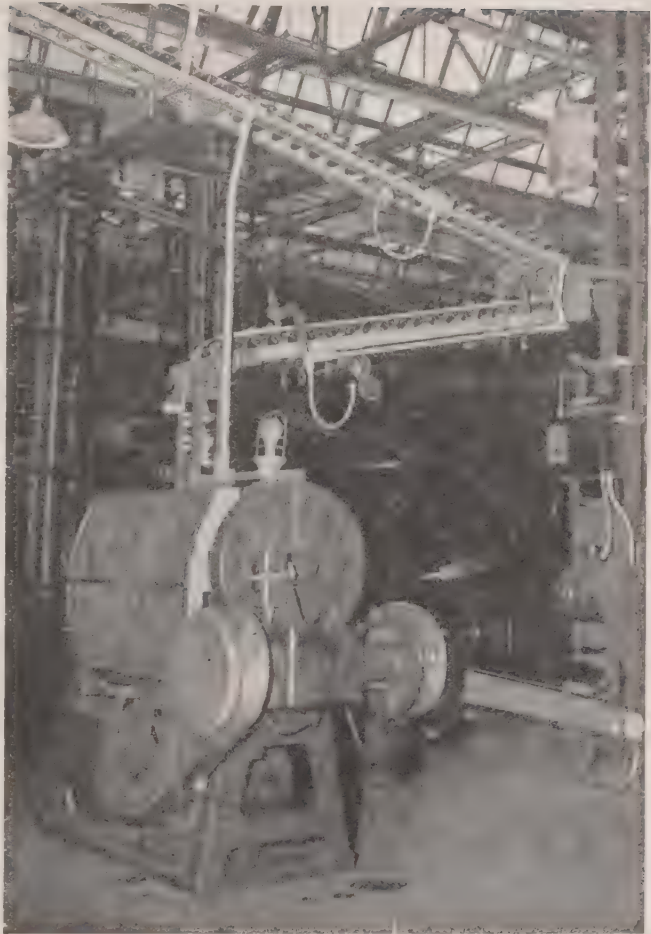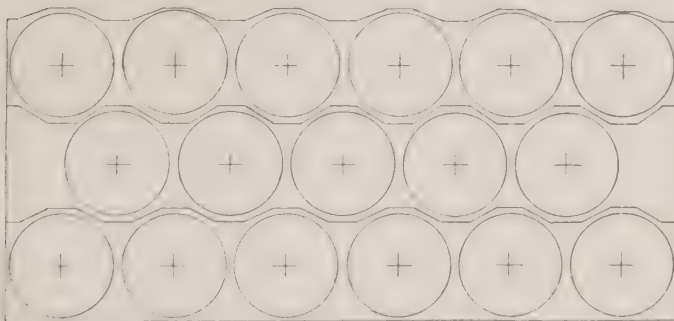
A cross section of

Fig. 40. Diagram illustrating method of stamping can ends to secure maximum economy of tinplate consumption.
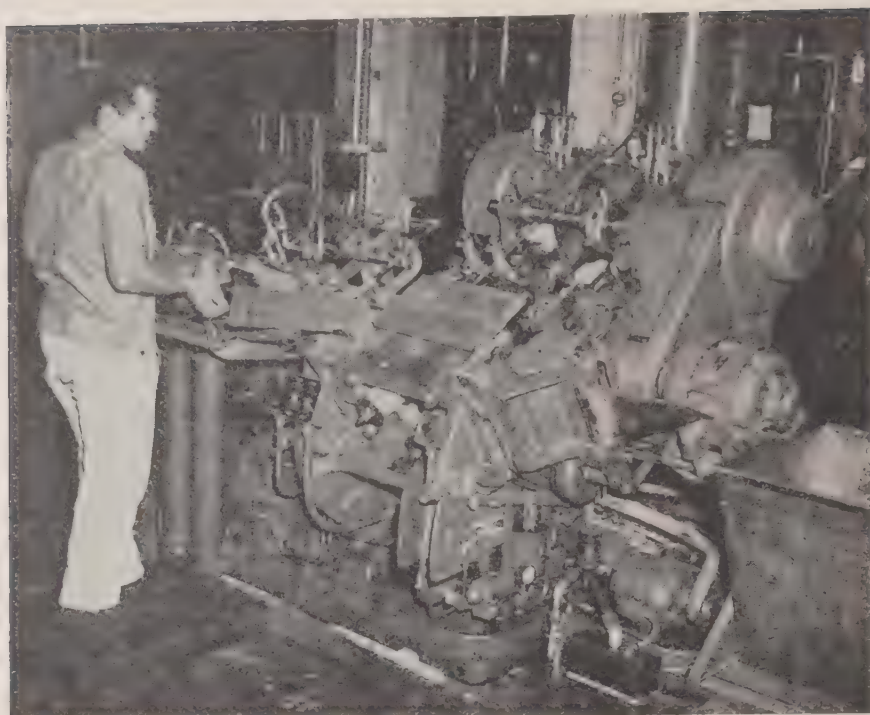
FIG. 41.   Automatic strip feed press for the stamping of can ends from
scroll sheared blanks.
(*Courtesy American Can Co.*)

a typical can end is shown in Fig. 42.   The expansion rings serve
three purposes.   In the first place, they facilitate the flexing of the
can end during processing and thus relieve the strain on the can
seams.   Secondly, they allow the can end to bulge more easily if any
pressure is developed due to spoilage of the can contents, thus acting
as a warning to the consumer.   Finally, the flexing of the ends ensures
tight seams in the event of slight wear of the double seaming rolls
and chucks during use.
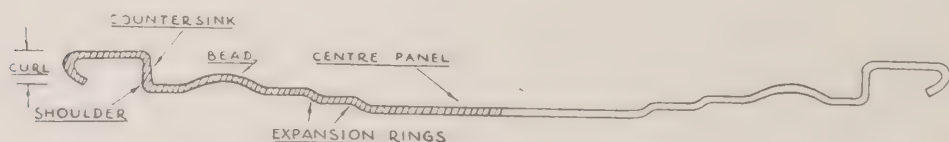
FIG. 42.   Cross section of typical can end.

The position and size of the expansion rings varies somewhat with
different can makers and numerous types of ends have been suggested
as being particularly advantageous, and Clayton[2] has pointed out
that the pattern of the ends has been determined largely on an
empirical basis and that it would be possible to derive a mathematical
solution to the problem of the optimum pattern in terms of the

number of expansion rings, their diameter and height and whether the rings should be complete or in segments.

Can ends are stamped with a started edge, thus giving a lead for the curl and at the same time minimising the wear on the curling tools. The curling of the edge facilitates the double seaming operation, prevents the ends from nesting in the stacks, and also forms a channel for the reception of the lining compound, thus protecting it from injury during handling.

Curling is carried out on a curling machine, which is usually mounted between the legs at the back of the end stamping press as shown in Fig. 43. The machine consists of an outer stationary ring
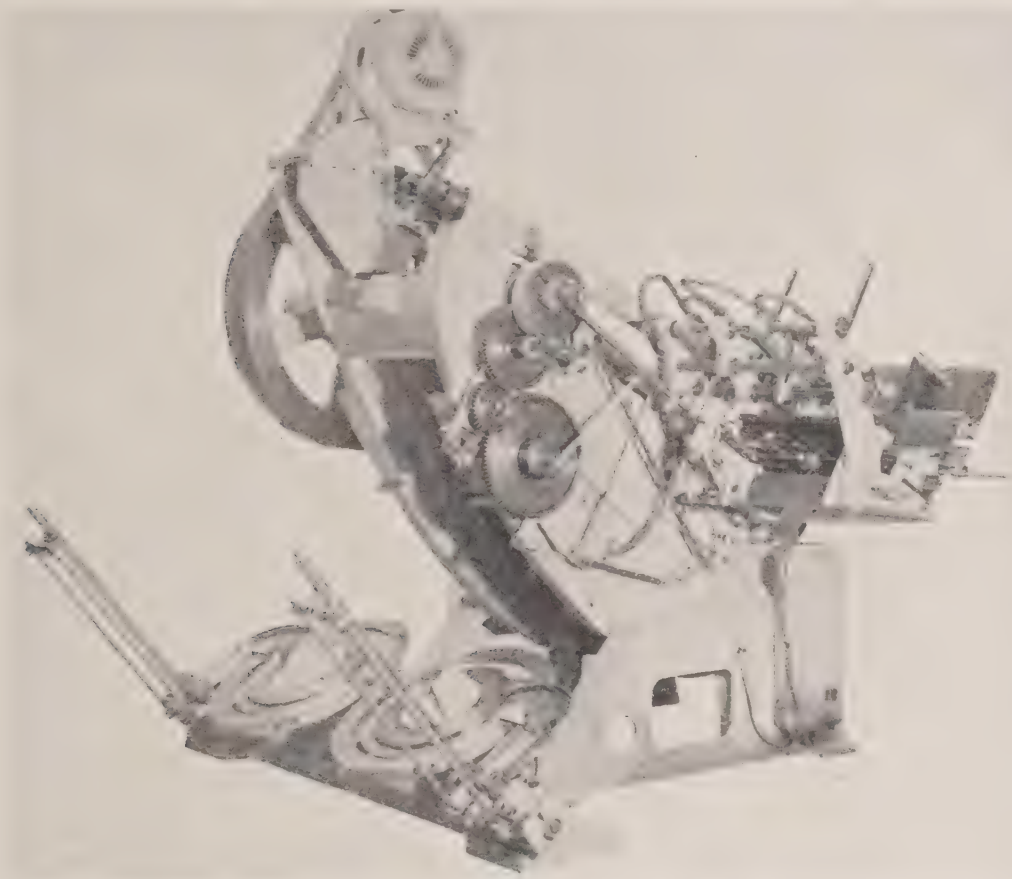
Fig. 43. Curling machine mounted between the legs of end stamping press.
(*Courtesy E. W. Bliss Co.*)

and an inner rotating disc, the outer ring being mounted eccentrically with respect to the inner disc so that the stamped end which enters at the wide point of the track is forced to rotate by the motion of the inner disc and at the same time to travel along the progressively narrowing space between the inner ring and outer disc, thereby

curling the edge. The height of the curl varies between .074 in. and .080 in. and it is usual to check the height of the curl from time to time by counting the number of ends in a stack of given height and comparing this with the number which should be present if the height of the curl is within the required limits. The curled ends are collected from the discharge end of the curling machine and transferred to the feed magazine of the compound-applying machine. Many substances have been used as lining compounds, but the two most popular have been a solution of rubber in benzol and a water-base emulsion of rubber latex. The latter compound has now superseded the former as the benzol solution although being satisfactory had several inherent disadvantages, among them the fact that the solution was inflammable and also that there was a tendency for the contents of the can to become contaminated with benzol if the solvent had not been completely eliminated before double seaming. The latex emulsion on the other hand has no such disadvantages.

Among the requirements of a good lining compound are the following :—

(1) It must be non-toxic and must not impart any flavour or odour to the can contents.
(2) It must be of uniform consistency.
(3) It must be stable over a wide temperature range.
(4) It must not shrink or disintegrate on drying and must form a uniform film on the can end.
(5) It must be sufficiently resilient to compensate for any variation in tinplate substance and other small defects in the seam.

As the canner has to carry out a double seaming operation on the filled can it is particularly important that he should appreciate the functions of the lining compound, and realise that it is not intended to compensate for major discrepancies in the double seam due to maladjustment of the seaming machine, for example, but solely to fill any minute discontinuities resulting from variation in tinplate substance or other causes. In fact, given ideal conditions and no variation in tinplate, etc., it is perfectly possible to obtain an hermetic seal without any lining compound. These conditions, however, cannot be maintained in practice and it is therefore necessary to use a lining compound if uniform air-tight seams are to be obtained.

The can ends stacked in the feed magazine of the compound-applying machine are automatically fed from the bottom of the magazine to a chuck, which centres the ends and rotates them for approximately two revolutions under a nozzle which applies a thin uniform film of lining compound in the recess formed by the curl and

shoulder of the can end. The ends are next transferred to a drying oven which may take the form of a small furnace through which travels an endless belt conveyor on which the can ends are placed, or a rotary drier may be used in which the can ends are rotated at the same time as they traverse a vertical column through which heated air is driven.

The amount of compound applied varies with the size of the end and the consistency of the compound, but approximately 30,000 211 x 400 ends can be lined with a gallon of latex compound.

When the lining compound has been dried the ends are either packed in paper sleeves for transport to the canner for seaming on the filled cans, or they are sent direct to the double seaming machines in the can making line for use as maker's ends.

Double seaming machines for attaching the can ends to the bodies are of many different types but they all possess the same fundamental parts, namely, a baseplate on which stands the can to be seamed, a chuck which fits snugly into the end to be seamed, and the seaming rolls. The exact mode of operation of the seaming machine depends on its design, but the following description may be considered typical. The can bodies are delivered from the flanging machine and are automatically covered by an end from the magazine on the double seamer, the can with end then passes to the baseplate where it is lifted automatically causing the chuck to engage the countersink of the can end thus holding the can firmly in position. The first operation seaming rolls then come into operation and roll or curl the edge of the can end under the flange of the body. The second set of rolls then comes into operation and completes the seam by flattening the hooked edges of the can body and the can end against the body of the can, thus forming an air-tight double seam. The finished double seam when correctly made produces an air-tight seal, but slight maladjustment of the seaming machine or variation in the thickness of the tinplate may result in a seam unable to withstand the strains involved in handling and processing, and for consistent results it is essential that the finished seam should conform to the dimensions given in Chapter 8. The regular examination of seams both in the cannery and at the can-makers' plant ensures that the seams produced are within the necessary tolerances, and that the seaming machines are kept in first class condition by carrying out adjustments as soon as any variations are observed in the seam measurements.

Modern double seaming machines are equipped with a number of seaming heads and operate at speeds of 150–300 empty cans per minute. The finished cans from the double seaming machine are delivered to the can tester. Vacuum or compressed air testers have replaced the old type of tester in which each can was subjected to

air pressure while immersed in water, defective cans being denoted by the stream of bubbles rising from the leak. The modern can tester applies air pressure to the cans while they are held in pockets located round the periphery of the testing wheel, the pockets and the open ends of the cans being sealed by means of rubber pads. Fig. 44 shows a machine of this type. The space outside the cans but inside the pockets is initially at atmospheric pressure, but if the can leaks a pressure in excess of atmospheric is developed as the testing wheel revolves, and this excess pressure is transmitted by means of a sensitive diaphragm to a device which automatically rejects the defective can. Sound cans are dropped into a runway leading to the packing room or can store.
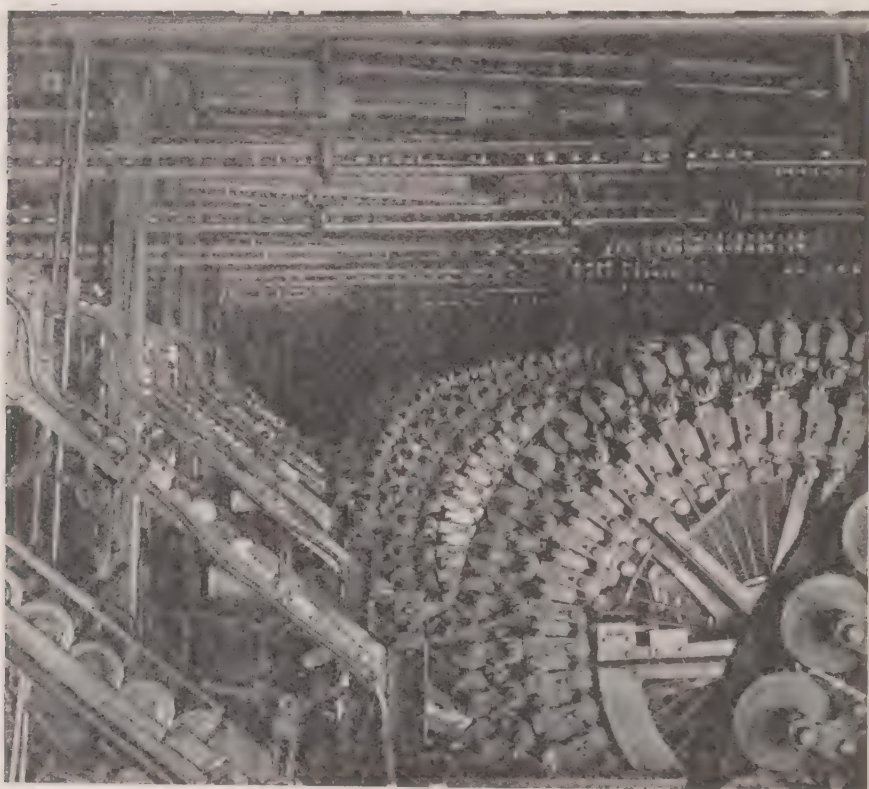
FIG. 44.   Continuous can tester.
(*Courtesy American Can Co.*)

Cans found to be defective are usually retested in a water bath and the defect is located and examined so that any defect in the can-making line may be immediately corrected. The efficient operation of the testers safeguards both the can maker and the canner and it is common practice for the can-maker to guarantee that not more than two or three cans per thousand will leak due to faulty manufacture.

The completed cans are packed in fibreboard cases which are the property of the canner and will be used by him for sending out the filled cans, or they may be packed loose into a paper lined railway van or container.

Although the majority of the open top cans manufactured are cylindrical, increasing use is being made of the square-sectioned can for such products as corned beef and other solid meat packs. Formerly cans for these packs were fully soldered, largely because of the difficulty in producing an hermetic seal with a square-sectioned can, the sharp change in radius at the corners being a point of weakness. These difficulties have now been overcome and there is every reason to suppose that the solderless open top type of can will eventually supplant the fully soldered variety for the above purposes.

The method of manufacture of the square-sectioned can follows the same lines as described above for the round open top can. It is, however, frequently desirable to incorporate a key opening device and this entails an extra operation in which the can bodies are scored along the line of opening, this process being carried out before the body blanks are fed to the body maker. A further modification is that the can ends are usually lined with compound by a process known as die-lining, the compound being applied to the end after stamping and before curling, by a specially constructed die. By this means a more uniform coating of compound is applied to the ends, particularly at the corners which are inclined to be skipped if the same method as that used for round ends is employed. After the compound has been applied the edges of the ends are curled in the usual manner.

The double seaming of the square-sectioned cans calls for special care as the sharp change in direction which occurs at the corners may cause trouble if the seaming machine is not properly adjusted. It is usual to run can lines making this type of can at speeds of 100 to 120 cans per minute.

A development of interest to canners located at considerable distances from can making plants where the carriage rates on cans are high, is the flattened can. The body of the can is made in the normal manner, but instead of seaming on a makers end, the body is flattened and packed separately from the tops and bottoms which are stamped and lined in the usual manner. The canner on receiving the flattened can bodies reforms them into cylinders on a reforming machine and seams on a bottom, often using the same seaming machine as that used in seaming the filled can. By this method a considerable reduction in freight space is effected, in the case of the 307 x 408 can size, for example, a saving of nearly four-fifths is achieved.

The Fully Soldered Can

The fully soldered can is still made in large numbers for the packing of condensed and evaporated milk, and although old in design the production of this type of can has been increased to almost the same level as that reached by the open top can. It is common practice, both in the United Kingdom and the United States, for the large dairy companies to make their own cans near the can filling lines and thus to effect considerable saving in transport charges. The body of the condensed milk type of can is made in exactly the same manner as that used for the open top can except that the body blank is not notched, this operation being unnecessary with the soldered end seam. The soldered can bodies are next transferred to a rotary header which automatically attaches both ends of the can, which are stamped in such a way as to be a tight fit over the ends of the body. One end has a small hole through which the can is filled, the hole being finally closed with solder. In another type of condensed milk can a larger hole is left for filling and this is closed with a small tinplate cap which is soldered in place after the can is filled.

Soldering the ends on either type of can is carried out by rolling the can inclined at an angle along a trough containing molten solder, the trough being about 5ft. long. The level of the solder bath is kept constant so that only the seam being soldered dips into the solder. When one end has been soldered the other end is similarly treated by reversing the angle of the incline. Cheftel[3] has pointed out that with the soldered type of seam the amount of steel base exposed by mechanical damage of the tin coating during seaming is reduced to a minimum. A further advantage of the soldered end seam is that it effects a slight economy in tinplate by the fact that no metal is rolled into the seam as is the case with the double seam.

For many years the packing of corned beef has been carried out in a rectangular-sectioned tapered soldered can similar in construction to that used for condensed milk, but it is now being rapidly replaced by a can of similar shape with double seams and compound-lined ends.

The Deep-Drawn Can

The third type of can in common use is the "deep-drawn" can which is used for packing fish and fish products. This can, in contrast to the open top can, has only two component parts, the bottom and sides being fabricated from one sheet of tinplate while the top is double seamed. Cans of this type are usually shallow, the depth being limited by the diameter, but the development of cold-reduced tinplate with its increased ductility has made possible the manufacture of cans of greater depth.

The fact that deep-drawn cans have only a single end seam and no body seam is an advantage from the point of view of leakage and corrosion resistance, but against this must be weighed the fact that in deep drawing the tinplate is heavily strained and the tin coating is sometimes damaged, as also is any lacquer coating which may be present ; furthermore the sharp change in radii which occurs in the case of the rectangular and oval-shaped cans tends to make the double seaming operation more difficult as there is a tendency to form wrinkles, but this can be compensated to some extent by the use of extra heavy films of end-lining compound.

The oval and rectangular shapes commonly used for fish packing are particularly convenient as they permit the fish to be packed tightly in the can without damage, and when the can is opened the contents can be easily removed.

Aluminium and its alloys are finding increased use in the fabrication of deep drawn cans, as these materials are relatively easy to draw, and being of uniform composition throughout their thickness do not suffer the same damage during drawing as is the case with tinplate. Can-makers in Norway have been particularly prominent in the use of aluminium and its alloys for can making and a more detailed consideration is given in Chapter 12.

Lacquers and Protective Coatings

Lacquers and protective coatings on tinplate serve two complementary purposes :—

(1) They protect the tinplate against corrosion by the can contents.
(2) They protect the can contents from the effects of metallic contamination.

Lacquering of the interior of the can was, according to May[4], first used to counteract the tendency of canned beets, cherries and other highly coloured products to bleach or fade when packed in plain tinplate cans, but the use of lacquer received greater prominence as a means of preventing the blackening of the can and its contents which occurs with some foodstuffs, notably meat and fish products, certain vegetables, and dairy products.

The formation of black stains both on the interior of the can and on the can contents when sweet corn was packed led Bohart[5] to develop the so-called "sulphur-resisting" lacquers. These lacquers, as already stated, contain a substance in suspension which reacts with the sulphur compounds liberated during sterilisation to form a white sulphide instead of the black sulphide of tin or iron. Zinc oxide is commonly incorporated in the lacquer for this purpose.

The formulation of a lacquer suitable for coating the interior of food containers is not an easy matter, as in addition to possessing a high degree of adhesion, elasticity and toughness, the lacquer must be odourless, non-toxic, and unaffected by the foodstuffs with which it comes into contact, nor must it impart any flavour to the can contents. Furthermore it must be stable over a wide temperature range and not break down during processing. Lacquers for the interior of food cans have been divided by Farrow and Green[6] into the following types :—

(1)   Acid-resisting clear lacquers.
(2)   Sulphur-resistant lacquers.
(3)   Double-coated meat lacquers.
(4)   Phenolic meat lacquers.
(5)   Lacquers for deep drawing.

The acid-resisting class of lacquers is used in packing fruits which would otherwise corrode the can by virtue of their acidity, or for the highly coloured fruits which would suffer bleaching due to the reducing action of the tin salts which would be liberated by the action of the fruit acids on tinplate if the lacquer film was absent. The majority of lacquers of this type are made from natural or synthetic resins combined with drying oils and a drier. Little information is available on the formulation of canning lacquers of this type, but the analysis of a number of Norwegian and English lacquers has been published by Jakobsen[7]. Sulphur-resistant lacquers, as already stated, are used for packing products which liberate sulphur compounds during processing, resulting in the production of black iron or tin sulphides which although harmless detract from the appearance of the pack. The acid-resisting lacquers do not prevent staining of the interior of the can, but, as already stated, when proportion of zinc oxide is incorporated in the lacquer the liberated sulphur compounds react with the zinc oxide to form zinc sulphide which is white, only appears as a faint opalescence in the lacquer film.

When used with meat packs a lacquer must be capable of withstanding higher temperature than is the case with the acid-resisting lacquers used for fruit packs, which normally undergo processing at 212°F. for between 10 and 30 minutes. Meat packs, on the other hand, may be processed at temperatures ranging up to 250°F. for as long as 2 hours, and the lacquer formula has to be modified accordingly.

The pigmented lacquers, according to Farrow and Green[6], are sometimes subject to pinholing and the adhesion may also be poor. In some packs such as meat roll, for example, the lacquer film has been known to adhere to the can contents and be completely removed from the can when the contents is extracted.

The double coated meat lacquers were developed mainly to overcome the difficulty of poor adhesion referred to above, but they have now been largely replaced by the phenolic lacquers recently developed in America.

The phenolic lacquers represent a departure from the normal type of oleo-resinous lacquer ; they do not contain oil, and consist of a synthetic resin dissolved in a solvent usually consisting of a mixture of alcohols and hydrocarbons. The drying process, after evaporation of the solvent, polymerises the resin forming a hard yet flexible film which adheres extremely well to tinplate, provided that the film weight is carefully controlled and the lacquer film is adequately stoved.

Lacquers for deep drawing must be capable of withstanding considerable deformation, and the development of the phenolic resin type of lacquer has made possible the production of a lacquer with good sulphur-resisting properties combined with sufficient elasticity to withstand deep drawing. The oleo-resinous lacquers formerly used were not resistant to sulphur staining, while pigmented lacquers of the same type did not stand up to the deep drawing operation.

The application of a uniform film of lacquer is extremely important, particularly so in the case of tinplate to be used for the fabrication of cans for acid products. The most generally used method at the present time, is roller coating of the tinplate sheet before fabrication into cans, and a typical machine for this purpose has been described by Farrow and Green[6], the main essentials being shown in Fig. 45. The application roller is made of a rubber-like material consisting of
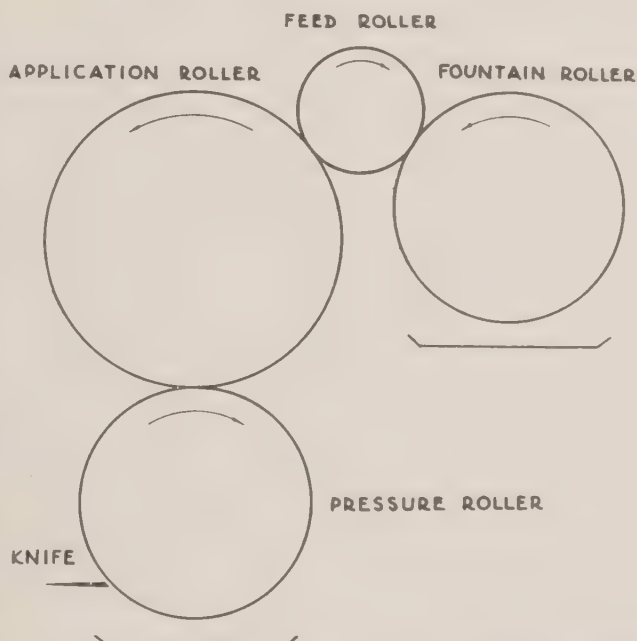

FIG. 45. Schematic diagram of sheet lacquering machine.
(*Farrow and Green*)

gelatin modified with glycerine, while the other rollers are made from steel. The application roller may have grooves cut in it at points where it is desired to leave a bare strip of tinplate, as for example, at the side seam to facilitate soldering. In operation the fountain roller

rotates in the bath of lacquer and transfers a film of lacquer to the feed roller which in turn transfers it to the application roller ; by this method the lacquer is spread in a uniform film on the application roller before transfer to the tinplate. The application of a film of constant film weight is a matter of considerable importance and the thickness of the applied film is controlled by the distance apart of the feed roller and the fountain roller, while the thickness of the dried film depends on the composition of the lacquer and its viscosity. The film weight varies with the lacquer used and also with the purpose for which the finished can is intended, but with the oleo-resinous lacquers a typical value is 5 mg./sq. in., while with the phenolic meat lacquers 2 mg./sq. in. may be considered typical. After application the lacquer film is stoved, usually in a travelling oven which conveys the lacquered sheets through a heated tunnel, the rate of travel and temperature being so adjusted as to dry the lacquer by the time the sheets emerge from the oven. On modern stoving ovens the stoving temperature is controlled by a thermostat and a recording thermometer gives a permanent record of the temperature at which the oven is working. The temperature of stoving varies considerably and is usually higher for the synthetic resin type of lacquer than for the oleo-resinous type ; Jakobsen[7] gives temperatures of 190–220°C. and 160°C. for the two types of lacquer, respectively.

The application of lacquer before fabrication of the container has the disadvantage that no matter how perfect the coating, mechanical damage of the film during fabrication is inevitable, the main sites of damage being the side seam and the shoulders of the can ends. Moreover, it is impossible to avoid exposure of metal at the overlap of the notches in a lock-seamed can. Reference is made in Chapter 3 to the desirability of applying at least one coat of lacquer after fabrication, particularly with cans intended for packing fruits and acid vegetables, and several methods have been proposed for this purpose.

Prior to 1935, spray-lacquering was the only means envisaged, and experiments were carried out without leading to any commercial application of the process. In 1935 was filed a patent by Clayton, Sumner, Morse and Johnson for the internal coating of fabricated cans by electrodeposition from a lacquer emulsion, and the publication of this specification[8] in the following year aroused widespread interest in the possibilities of "post-lacquering." This process is considered later in this chapter, in connection with other patents by Clayton *et al.* In 1938 appeared the method of "flush-lacquering," in which a specially formulated lacquer of low stoving temperature is used to form a film over the can interior by pouring some lacquer into the can and then pouring it out again while the can is being rotated.

Both spray-lacquering and flush-lacquering suffer from the disadvantage that to obtain a film of suitable thickness the lacquer must be diluted to a relatively low viscosity, and difficulty is found in preventing drainage from convex areas, such as bends and corrugations, before the film is stoved. For this reason the most successful results have been obtained with cans fabricated from previously lacquered sheet, "post-lacquering" being used as a means of coating the uncovered areas which arise mainly from damage during fabrication. With spray-lacquering, if desired, the post-treatment may be confined to the side seam of the body before the end is seamed on. In this respect these mechanical methods differ fundamentally from the electrodeposition process, in which the whole internal surface of the fabricated can or body is coated in one operation : this is made possible by the use of lacquer in emulsion form, the viscosity of the lacquer itself being high while that of the emulsion as a whole is low.

With any method of post-lacquering cans, the difficulty must be faced that formed cans occupy considerably more space than the equivalent area of flat sheets, so that to retain a reasonable rate of production the stoving plant must be of considerable size. Furthermore, the temperature of stoving must not rise much above 170°C., otherwise there will be a danger of melting the solder in the side seam.

The results so far obtained, however, in tests with cans lacquered after fabrication, encourage the view that for certain fruit packs the extra cost involved will come to be regarded by canners as well worth while, particularly for packs which are to be stored in a hot climate. It is probable, therefore, that post-lacquering will find commercial application when the engineering difficulties of application and stoving have been overcome and economic conditions are again favourable to technical improvements of this kind.

Interest in alternative methods of protecting tinplate, as well as in the internal coating of fabricated cans, has been stimulated largely by the work carried out in Clayton's laboratory, which has resulted in a series of patents, [8, 9, 10, 11, 12, 13, 14 and 15] describing various new electrochemical processes applicable to can-making. This work derived its origin from Clayton's interest in the characteristic variations in the intensity and character of sulphide staining by meat and vegetable packs, which were observed with tinplate from different manufacturers. Sumner found that these differences could be correlated with variations in the air-formed oxide film normally present on tinplate, and that staining could be prevented altogether by an artificially produced oxide film. The method chosen was to make the tinplate surface the anode in an electrolyte solution incapable of yielding a soluble tin salt, so that oxidation of the tin

surface occurred in a controlled manner on electrolysis. A later development giving improved results consisted in first removing the air-formed oxide film, by a novel form of electrolytic treatment in the same solution as was used for the anodic oxidation[8]. There was little difference in the protective value of films from different electrolytes. In the early experiments a dilute solution of ammonia and/or ammonium carbonate was used, but in pilot plant developments a nearly neutral solution containing mono- and di-sodium phosphates, in equimolecular proportions, was adopted.

This electrolytic process suggested to Clayton the possibility of forming a film of lacquer on the tinplate surface by anodic deposition from a lacquer emulsion, and successful preliminary tests of this idea led to its intensive development as a means of lacquering cans internally, after fabrication[9, 10]. Emulsions of lacquer in dilute ammonia were used at first.

Sumner, who was mainly responsible for the detailed investigation, has given a general account of this process[16], in which he describes how a consideration of the mechanism of deposition led him to produce protective films containing aluminium oxide, by anodic treatment of tinplate in sodium aluminate solution. This step was mainly valuable in leading to his important discovery that other material emulsified or colloidally dispersed in sodium aluminate solution could be co-deposited with aluminium oxide (or hydroxide) in controllable proportions, and that by this means extremely tenacious films could be produced. In this way the continuity and uniformity of the film were considerably improved. First applied to the co-deposition of alumina with lacquer itself[11], this new principle was later extended successfully in the same laboratory to the co-deposition of alumina and/or silica with waxes[12] (for coating beverage cans), with drying oils[13], and with various colloids, notably starch[14]. In all these processes simultaneous anodic oxidation of the tin surface occurred, but for lacquered cans intended to give protection against sulphide staining it was preferred to carry out anodic oxidation as a separate step, before the deposition of lacquer.

All these processes are applicable to mass-production lines, since the duration of electrolytic treatment is a few seconds only, but even so, to keep pace with modern high-speed can making plant considerable equipment would be needed for the treatment of finished cans, and this has been the main deterrent to commercial exploitation. It is an interesting speculation, as to whether these processes would have come into use had they been developed at a time when can making speeds were considerably lower.

Particular interest attaches to the starch/aluminate process, which gives a coating remarkably resistant to sterilisation conditions and

capable of withstanding sulphide staining under certain conditions where the simple anodic oxide film breaks down. The process is therefore very suitable for cans intended for meat, vegetable and similar packs, and can be applied either to flat sheets or to formed cans as an alternative to lacquering. Originally suggested by Clayton as an extension of the "co-deposition" principle, this was ultimately selected (by the purchasers of the patents) as the most promising of the electrochemical processes for commercial development, and considerable (unpublished) work was done on it until war conditions made it impracticable to pursue investigations of this kind.

The appearance of Sumner's patents on protection against sulphide staining by anodic oxidation led to considerable work, both in this country and in America, on alternative methods of obtaining the same result. In this connection it is of interest to note that a U.S. patent[17] for a meat can having a chemically oxidised interior surface, actually antedates Sumner's independent discovery. Considerable success in developing a method of chemical oxidation has been achieved by the Tin Research Institute and has been described by Kerr[18, 19]. A somewhat similar process is the subject of a U.S. patent[20], while other U.S. patents[21, 22] relate to electrolytic processes. Kerr's process does not require intricate equipment, and as it can be used by the canner to produce a protective coating on the fabricated can (and has in fact been so used), it is described in detail in the following paragraphs.

The method as originally developed required an immersion time of 5 minutes in the treatment bath, but by modifying the solution it has been found possible to obtain a high degree of protection in a time as short as 20 seconds. Kerr[23] has stated that the final solution adopted was as follows :—

Trisodium phosphate (crystalline) ..	20 grm.
Sodium dichromate	8 grm.
Sodium hydroxide	20 grm.
Dispersol L or Teepol	3 grm.
Water to make	3 litres.

The tinplate to be treated is immersed in the above bath for 10-60 seconds at 70-80°C. followed by rinsing in water.

Kerr[22] gives a report of experiments carried out by treating sheets of tinplate from which cans were subsequently fabricated, and also by treating the fabricated cans both internally and externally. Results obtained with a variety of foods are shown in Table VII. It will be seen that the process also tends to reduce the amount of tin dissolved by the food, acting in a similar capacity to lacquer in this respect.

TABLE VII

Examination of Contents and Inspection of Interior of Cans Made from Treated and Untreated Tinplate Stored for Three Months at Room Temperature

(Kerr)

Pack	Appearance of interior		Tin content of food parts per million	
	Treated	Untreated	Treated	Untreated
Meat and kid-ney pudding	Slight staining	Very heavy staining	27.2	45.6
Beans in tomato sauce	No etching or staining	Some etching and moderate staining	78.5	103.4
Oxtail soup	No staining	Very heavy staining	37.5	47.0
Meat roll	Very slight staining	Very heavy staining	30.8	41.0
Vegetable soup	No staining	Slight staining	30.2	63.0
Clear oxtail soup	No staining	Heavy staining	28.2	33.0
Stewed steak and vege-tables	No staining	Very heavy staining	45.4	55.0
Irish stew	No staining	Very heavy staining	29.7	31.2
Scotch broth	No staining	Very heavy staining	22.0	26.7
Fruit pudding	No staining	Very slight staining	44.3	77.3

The protective action tends to fall off as the pH value of the contents is reduced, but as the majority of the packs which produce sulphur staining have pH values above the lower limit at which the coating begins to break down the process has considerable value.

An extensive study of the various lacquers and protective coatings for the interior and exterior of cans has been made by Kefford and Lynch[24], who confirmed the action of the electrolytic and chemically produced protective films as well as comparing the behaviour of a number of different lacquers.

Although the only lacquering operation likely to be carried out by the canner is on the exterior of the can, it is essential that he should be conversant with the properties of the different types of lacquers likely to be used by can makers and thus be in a position to decide which particular lacquer is best suited for a given product.

The testing of lacquer films is primarily the responsibility of the lacquer manufacturer and the can maker, and a comprehensive scheme for the testing and evaluation of food can lacquers has been published by the British Standards Institution[25]. A number of the tests described might well be used by the canner if at any time it is desired to check the lacquer coating on cans received from the can maker, the factors of major importance being the continuity, adhesion, and film weight of the coating, also its ability to withstand processing.

In conclusion it must be emphasised that the complete solution to the problem of finding a protective coating for the interior and exterior of food cans has not yet been obtained, but any method of treating the cans after fabrication whether by lacquering, electro-deposition, or chemical treatment offers considerable advantages over the present method of simply lacquering the flat sheets before fabrication and thereby subjecting the lacquer film to the possibility of considerable mechanical damage during fabrication.

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CHAPTER 5

SOME GENERAL CONSIDERATIONS IN ESTABLISHING A CANNERY

In establishing a commercial cannery important factors *inter alia* which must be carefully studied are :—

(1) Availability of raw materials for canning.
(2) Site for cannery, type of building, and division of space.
(3) Duration of the canning season ; if short, what alternative packs will be available to maintain production.
(4) Transport available for raw materials and finished products.
(5) Availability of labour.
(6) Water supply and the disposal of cannery waste.

Availability of Raw Material

The first essential in the establishment of a cannery is to ensure that the supply of raw materials for canning will not be subject to depletion or exhaustion, and that they will be of suitable quality for canning. The quality consideration is most important in the case of fruit and vegetable products, as some fruits and vegetables, although excellent for the fresh market, are not suitable for canning.

In the event of competition with the fresh market the canner must ensure that the price he can afford to pay will be sufficient to obtain the necessary supplies of raw materials.

It has, therefore, become customary in America, and to a lesser but increasing extent in the United Kingdom, for the canner to grow his own supplies of vegetables from specially selected seed, or alternatively supply the seed to growers and contract to take the whole crop.

In the development of new areas the canner will frequently have to stimulate production of the type of raw material required if he wishes to exercise complete control over his materials.

In the establishment of a cannery where there will be seasonal fluctuations in the supply of raw materials, as is the case in nearly all fruit and vegetable canning plants, it is important to ensure that some alternative product is available to fill in the slack periods and thus reduce the oncosts and permit the retention of key labour.

Site and Type of Building

The choice of a site will to some extent be controlled by the product or products to be packed : fruit and vegetable canneries, for example, should be located near the growing areas in order to reduce the time lag between picking and packing. Similarly milk and fish canning plants should be located in milk producing areas and fishing ports

More latitude is permissible in the siting of meat canneries, although in North and South America the meat packing plants are in many cases located close to the stock yards or cattle ranches, thus reducing transport to a minimum.

The ideal site is one where atmospheric pollution is reduced to a minimum, a plentiful supply of water is available for use in the cannery and in the boilers, and sufficient space is available to avoid overcrowding, and permit expansion.

With regard to atmospheric pollution it is particularly important that adjoining factories do not emit any objectionable fumes or otherwise contaminate the air.

As an instance of atmospheric pollution causing spoilage of canned food the case cited by Baumgartner and Wallace[1] is a good example. In this case fur dust blown from an adjoining factory was shown to contain exceptionally heat resistant spore-forming anaerobes which were identical with those isolated from blown cans of food.

A suitable site having been found the question of the type of building to be erected arises. On some sites a building may already exist, but only in rare cases will it be found suitable for a cannery and, although, adaptations have been carried out with some success, in most cases it will be found far more satisfactory to start *de novo* with a building designed for the job.

The design of a building has a great influence on the final efficiency of the factory and careful attention must be paid to the stuctural frame, floors, walls and roof.

A fundamental consideration of great importance is whether the factory should be a single or multi-storied structure. With few exceptions the single storied structure is cheaper in initial, maintenance, and operating costs, but where gravity flow is essential the multi-storied structure has an advantage, although, by the erection of suitable staging, equipment can be supported at different levels in the single storied factory.

The site value will to some extent influence the choice of the type of building, in an area with high ground rent, for example, a multi-storied building may offer substantial reductions in overheads by virtue of the smaller area occupied. On the other hand the cost of

lifts and stairways in a multi-storied building may be sufficient to offset any saving in ground rent.

The efficiency of a building is a function of the amount of working space available, as well as of the cost per unit area, and generally speaking the usable area in a single-storied building will be greater than in a multi-storied building of equivalent area.

A further advantage of the single-storied building is the increased flexibility in the layout of plant and equipment, as the absence of supporting columns and the fact that the floor loading capacity is only limited by the bearing capacity of the sub-soil, permits the interchange of heavy machinery without any special strengthening of the building, etc.

The single-storied building permits easier supervision of the factory as an unobstructed view of all operations can be obtained. Ventilation and lighting are also facilitated as the walls and roof can be fully utilised.

In practice fruit and vegetable canneries are usually single-storied while meat and to a lesser extent milk canneries are multi-storied.

There are, of course, exceptions to this generalisation and no hard and fast rules can be laid down.

The enormous meat packing plants in the United States and the frigorificos in South America probably represent the ultimate development in multi-storied cannery design. In some of these plants cattle are driven along ramps leading to the killing floors at the top of the factory and pass down from floor to floor until they reach ground level in the form of carcases or canned meat.

Whether a multi or single-storied building is chosen it is of paramount importance to allow sufficient space for efficient operation. Nothing is more conducive to bad hygienic conditions than a cramped and badly laid out factory.

Division of Space

In allocating space to each department consideration must be given to the types of product to be packed and the scale of the operations. Provision must be made to allow the maximum flexibility of each line ; particularly is this true in canneries packing products of a seasonal nature.

Any canning process may be roughly sub-divided into four steps as follows :—

(1) Receiving raw materials, and sometimes storing until required for use.
(2) Preparation of raw materials.
(3) Filling, exhausting, closing and processing.
(4) Finishing and inspection.

The division of space must be in proportion to the space required for the various steps in the process. Fruit and vegetable canneries, for example, will require a greater area for the preparation of the raw materials than will milk canneries. Similarly, meat canneries will require the provision of cold storage space, and it is also desirable that the meat preparation department should be maintained at as low a temperature as is compatible with efficient working, thereby reducing the rate of increase of the indigenous bacterial flora on the surface of the meat, and reducing the risk of spoilage.

The space and equipment for the reception of raw materials will vary considerably, not only with the type of product, but also with the method of delivery. Less space will be required, for example, where there is a steady throughput as in the case of milk, than in a meat cannery where a variety of materials such as meat, cereals, spices, etc. have to be held in store. The reception department for raw materials must be equipped with some means of checking the quantity arriving and in certain cases it may be desirable to make provision for the immediate sampling of incoming raw materials, particularly where perishable products are involved.

The receiving area should be conveniently located with reference to rail and road transport and where perishable products are handled it is convenient if it is also close to the raw material preparation department, thus avoiding undue delay between receipt and preparation.

Provision must also be made for handling the non-food materials, among which cans are the most important item. As already stated in Chapter 4 cans are supplied by the can fabricator either in fibreboard cases or packed directly into paper-lined containers as shown in Fig. 46. When supplied in cases the cans are frequently left in the cases until required and then transferred directly to the filling lines. Where railway containers are used, as is usually the case in the larger canneries, conveyors are required to carry the cans from the containers to the can store, or in some cases when can stocks are low as may be the case at the height of the fruit and vegetable or milk packing seasons, the cans are fed from the railway containers directly on to the filling lines.

In allocating space for the preparation room it is a common fault to allow too small an area with the result that both the quantity and quality of the output suffer.

The preparation room must be adequately equipped with steam and water points so that the whole area can be frequently washed down without dragging long lengths of hose across the floor.

In common with most of the departments, the preparation room will be subject to a considerable degree of moisture on the floor and

for that reason particular attention must be paid to the type of floor chosen. The factors to be considered in selecting a particular type of flooring material are :—

    (1) Resistance to chemicals.
    (2) Resistance to wear.
    (3) Slip proof qualities.
    (4) Ease of cleaning.
    (5) Cost.

The local conditions will determine to a large extent the relative importance of the above factors and it is difficult to lay down any

Fig. 46.   Bulk loading of cans into paper-lined railway container. The pronged stick permits the handling of many cans at one time.
(Courtesy American Can Co.)

hard and fast rule for the type of flooring to be used. The reasons for the failure of different types of flooring in food plants have been considered by Kanegsberg[2], and the same author[3] has discussed the selection of materials for flooring and the effects of varying processing conditions on a variety of such materials.

All floors must be properly sloped so that pools of standing water are avoided, a fall of about $\frac{1}{4}$in. per foot is common and no portion of the floor should be more than 18-20ft. from drainage channels. These channels are best made from half round white tile sections which can be enclosed with a perforated cover at points over which it is necessary to wheel bogies or trucks.

A slippery floor is bad for the confidence of employees and slows down the rate of production and in this connection Johnston[4] mentions that a resilient quiet flooring has been shown to increase output. Frequent cleaning is a great help in avoiding slippery floors, but the provision of non-slip footwear may be necessary in plants where greasy floors cannot be avoided.

The preparation room should be well lighted and kept free from steam by the provision of adequate ducts and extractor fans. The walls, in common with the rest of the cannery, should be tiled to a height of about 7ft., the remainder being painted white, while all corners of walls, ceilings and floors should be rounded to prevent the accumulation of dirt and debris and to facilitate cleaning.

The maintenance of clean conditions in the preparation department, particularly where root vegetables are handled, will be greatly facilitated if arrangements are made for a preliminary washing of raw materials contaminated with soil before they enter the preparation department proper.

A factory which looks clean and is easy to keep clean has immense psychological value and encourages employees to take a pride in their work and in their surroundings.

Where possible, partitions should be erected between the raw materials reception room and the preparation room, and also between the preparation room and the processing department ; by this means particles of food and debris such as soil, vegetable peelings, etc., will be more easily collected and will not be carried from one department to another, thus contaminating the whole cannery.

In a cannery handling a wide range of products it may be advisable to sub-divide the preparation room into sections such as vegetable cleaning, peeling, meat butchering, fish cleaning, gutting, etc.

In a large plant the installation of conveyors will economise in both man-power and time, but in the smaller organisation the initial outlay and maintenance may be uneconomic.

In the processing room where the exhausting and sterilising operations are carried out the atmosphere is often very humid due to the escape of steam, and ample provision must be made for the removal of this steam by means of ducting and suitable extraction equipment. The floor in the processing room must be particularly robust as it will have to stand up to a great deal of heavy traffic.

In the finishing department where such operations as incubation, lacquering, labelling and casing are carried out it is essential that the area should be dry and well ventilated and that there should be sufficient space for the easy transfer of stock. In some cases the finishing department will be combined with the warehouse in which the filled and cased cans are stored before delivery, and in this case it is of even greater importance that there should be no escape of steam from the processing department, otherwise there will be considerable danger of moisture condensing on the cans and rusting taking place.

In addition to the four basic requirements mentioned above, space will also be required for empty can stores, power and waste disposal plants, welfare, canteens, laboratory, etc.

Modern canning technology is far removed from the hit-and-miss methods adopted in the early days of the industry, and it has rapidly become a highly specialised field in which scientific methods are playing an ever-increasing part, and the place of a laboratory in a modern cannery should no longer, therefore, be regarded as a luxury, but as an essential part of the plant.

The work of a cannery laboratory is very wide in its scope embracing many branches of science, but it can be roughly grouped under the following headings :—

(1)   Examination of all raw materials.
(2)   Control of manufacturing processes.
(3)   Examination of finished products.
(4)   Development of new processes and new products.
(5)   Keeping the management fully informed of the implications of new technical advances likely to be of importance to the industry.

The examination of raw materials is an extremely important part of the work of the cannery laboratory for without uniform good quality raw materials a high quality product cannot be expected.

The examination of raw materials is more fully dealt with in Chapter 6 and should include cans, lacquers, adhesives, labels and the many other ancillary materials used in a cannery, in addition to the actual foodstuffs.

The control of the manufacturing processes also plays an important part in maintaining the quality of the finished product and here the laboratory must work in the closest co-operation with the foremen, charge hands and other employees.

It should become a routine matter for the various departments to send regular samples of the cannery output to the laboratory for

examination so that any faults in manufacture may be quickly discovered and corrected.

The examination of the finished products is of the same importance as the examination of the raw materials used in manufacture, and the laboratory should be made responsible for giving final permission before any batch of goods is despatched from the factory. This permission will be based on the laboratory work carried out during and after manufacture with particular reference to such factors as bacteriological condition, flavour, and appearance.

The extent to which the laboratory should devote its time to the development of new methods and processes is largely a decision to be made by the management, and will to some extent be dictated by the type and size of the cannery.

It is not possible, or in fact desirable, to lay down any specification for the size and equipment of the laboratory as so much will depend on individual requirements. The laboratory should, however, include, as the bare minimum, a general analytical section and a separate room for bacteriological work. In addition it is highly desirable for the laboratory to be equipped with a small scale pilot plant on which experimental batches of new products can be made before full scale production is commenced. The laboratory can exert a powerful influence on the quality of work produced by the factory by encouraging the application of scientific method and accurate control throughout the manufacturing processes; by so doing it will greatly ease the problems of management and also ensure a high quality and uniform product.

Finally a word must be said about the importance of frequent and regular attention to cleaning and the maintenance of hygienic conditions in the cannery. The time and effort expended on this will be amply repaid. The use of plenty of detergent and sodium hypochlorite solution will go a long way to reduce the bacterial flora which accumulate during the day. The steam sterilisation of small items of equipment is a very useful method of maintaining them in a clean condition. The personal hygiene of employees is another important factor, clean uniforms and headwear should always be available and adequate facilities for first-aid and washing should be provided.

Duration of the Canning Season

The oncosts of production will be greatly reduced if output can be so arranged to ensure an even level of production throughout the year.

Fluctuations are bound to occur, but by filling in the gaps in production with non-seasonal packs they can be reduced to a minimum.

Milk and fish canneries probably represent the most difficult problems in this respect as owing to the specialised nature of their plant, alternative products are difficult to find.

Fruit and vegetable canneries are also seasonal in character, but it is common practice to fill gaps in the annual programme with such products as processed peas, baked beans, repacked fruit salad, soups, etc.

Meat packing plants are fortunate in that supplies of raw material are available throughout the year and as these plants frequently combine a certain amount of products such as sausages, meat pies, etc., with their canning output they are able to keep running at a steady rate.

The chart, Fig. 47, shows the approximate periods during which some of the more important products are canned in Great Britain. These times will, of course, vary in different localities and with different climatic conditions, but the chart shows the seasonal character of certain products and also the non-seasonal products which may be used to balance production.

FIG. 47.   Chart showing approximate canning seasons for some of the principal products.

Transport

In the canning industry, as in most industries, transport plays an important part in the working of the factory. In the larger canneries it is an advantage to have a special railway siding so that incoming and outgoing goods may be dealt with without recourse to intermediate handling. This is particularly important in fruit and vegetable canning and in handling other easily damaged or perishable products.

Certain products may require road transport as in the collection of milk from outlying and often isolated farms, and under these circumstances it may be found economical for the canner to own his own transport fleet.

One problem common to all branches of the canning industry is that of handling empty cans. Reference has already been made to the methods adopted by the can maker in sending cans from his plant and the method of using a multi-pronged stick to pack cans into a paper-lined railway container. A method which might well be used by canneries in handling supplies of empty cans.

To the cannery situated at some considerable distance from the can making plant the flattened can referred to in Chapter 4 offers large savings in freight charges.

Labour Supply

Apart from raw materials the availability of labour is a factor of paramount importance in establishing a cannery.

The cannery located in a semi-urban district will generally be in a more favourable position to obtain labour, than the cannery situated in a purely rural area where a large proportion of the population will be engaged in farming and allied activities, and the density of population is generally less. On the other hand, the perishable nature of certain products such as fruit, milk, and vegetables often necessitates the siting of a cannery in close proximity to the producing areas.

Under these circumstances it may be necessary to arrange transport for the workers between their homes and the cannery.

The canning industry employs a high proportion of female labour and it has in the past been customary to engage workers for the season, in the case of a cannery packing seasonal products, and to rely on picking up workers when required ; under present conditions of labour shortage this practice is becoming more and more difficult and the smoothing out of fluctuations in production has become an important problem not only from the economic standpoint, but also from the labour angle.

The number of workers required depends on the size of plant, the type of product packed, and the degree of mechanisation of the

plant. No hard and fast rules can be laid down, but it is essential t[
have a nucleus of trained workers with a sound knowledge of th[
industry so that the less experienced workers may be trained.

Hitherto there has been little effort to provide facilities for th[
training of key personnel in the canning industry and it is encouragin[
to see that some firms are now starting trainee schemes to ensure [
supply of trained staff.

Water Supply

Water is a vital raw material in the canning industry, and in selectin[
a site for the cannery, consideration must be given both to avai[
ability and quality.

Although bacteriological purity is a *sine qua non* of water for [
cannery, other factors such as freedom from taste, dissolved solid[
metallic contamination, and acidity or alkalinity must also b[
considered. Water in a cannery is used for a number of purposes [
which the following are the most important :—

(1) Cooling of processed cans.
(2) Steam generation.
(3) Preparation of brine, syrup, etc.
(4) Blanching.
(5) Cleaning and preparation of raw materials.
(6) Cleaning of equipment, floors, walls, etc.

As seen from the above list, the quantity of water required by [
cannery will be substantial. In general, fruit and vegetable canneri[
will require most water, and meat canneries least.

Bacteriological purity is of particular importance in the water use[
for the cooling of cans, as any organisms which enter the can at th[
stage will not be subjected to a sterilising process, and will, therefor[
stand a good chance of surviving and causing spoilage.

As pointed out in Chapter 11, although, while chlorination may [
certain instances be permissible as a means of reducing spoilage due [
post-processing contamination it should only be adopted where it h[
been definitely proved that spoilage is due to the ingress of cooli[
water and where the can seams have been shown to be of norm[
commercial quality.

Although the chlorination of cooling water represents the main u[
of chlorination technique in the cannery, in some cases it may [
found desirable to arrange for the treatment of the entire suppl[
especially if town supplies are not available.

Many local authorities have continued the practice of chlorinati[
water, a process adopted as a precautionary measure during t[

recent war, and in most instances no further treatment is required, unless contamination is particularly heavy.

The efficiency of chlorination in reducing the number of organisms has been demonstrated by many workers. Merill, Cameron and Williams[5] for instance, showed that a reduction from 9,000 organisms per cc. in one cannery and from 100,000 per cc. in another plant to less than 25 per cc. was obtained by the addition of chlorine to give a residual chlorine content of 1 p.p.m.

Scott[6] cooled cans of corn in water containing the normal bacterial infection found in most canneries, and compared the number of blown cans with those obtained when similar cans were cooled in water containing varying amounts of chlorine ; in every case he found that the number of blown cans was reduced when chlorinated water was used.

There are several methods of chlorinating water of which the following are the most frequently used :—

(1) Simple addition of the requisite amount of chlorine in the form of gas or hypochlorite by means of a dispensing device arranged to deliver a pre-determined quantity of the chlorinating agent.

(2) Super-chlorination followed by dechlorination.

(3) Ammonia-chlorine.

The amount of chlorine to be added whichever method is adopted will vary with the type of water to be treated, the contact time allowed, and the temperature of treatment.

Chlorine is a powerful oxidising agent and any oxidisable matter in the water will absorb a certain amount of chlorine. This chlorine demand must, therefore, be met before any bactericidal action can occur and an appropriate allowance must be made when calculating the amount of chlorine required.

Equipment for chlorinating water is available in many forms, ranging from a simple device by which hypochlorite solution is allowed to drip at a steady rate under the influence of gravity into the water to be treated, to fully automatic devices injecting carefully measured quantities of chlorine gas.

It was shown by Race[7] that high concentrations acting for a short period were more effective than lower concentrations acting for a correspondingly longer time, and it was as a result of this work that the method of super-chlorination was developed. In this method a heavy dose of chlorine is given, sometimes as much as 100 p.p.m., then the excess is removed by sulphur dioxide, sodium bisulphite or other means. This method, however, does not find great application in the food industry.

In addition to the application of chlorine *per se* the use of chloramin
usually produced *in situ* by the addition of ammonia and chlori
has been suggested. The advantages claimed for this process are th
the chloramines formed by the reaction of the chlorine and t
ammonia are more stable than chlorine alone and as they are on
weak oxidising agents their efficiency as bactericidal agents is u
impaired by the presence of organic matter in the water. Th
action is, however, slower than is the case with chlorine and consid
ably longer contact times are required. In the application of tl
method it is customary to add the ammonia first, and then add t
chlorine after sufficient time has elapsed for thorough mixing of t
ammonia and the water.

The most generally used method in canneries, however, is that
adding chlorine in the form of hypochlorite solution or chlorine g
but irrespective of the method adopted it is essential that the dose
sterilising substances should be accurately controlled and that
should be thoroughly mixed in the water to be treated. In det
mining the residual chlorine it is important that samples f
examination should be obtained at the point of usage of the wat
otherwise anomalous results may be obtained due to change in t
chlorine residual from point to point.

There is considerable difference of opinion as to the amount
residual chlorine desirable, but a figure of up to 2 p.p.m. or in spec
cases 3 p.p.m. seems to find general acceptance.

The whole question of chlorination in the food plant, with particul
reference to the canning industry, has been dealt with by Harris[8] w
points out that in cooling tanks, continuous pressure coolers an
rotary open coolers conditions often favour the excessive build up
micro-organisms while in batch type retorts where the cooling wat
is not re-used there is less danger of contamination from th
cause. The same author also describes a simple device for tl
chlorination of cooling water by means of hypochlorite solution an
another device for the application of gaseous chlorine to wat
supplies.

The chlorination of water has also been studied by Hall an
Blundell[9] in connection with the elimination of undesirable odou
and the prevention of the formation of slime on the surface of equi
ment such as washers, gutters, flumes, etc.

Although too much chlorine may lead to the corrosion of cans a
other equipment, it is only when far in excess of those normally us
for the control of micro-organisms are employed that there is t
possibility of any serious corrosion taking place.

In conclusion the following points must be borne in mind wh
chlorination is being considered :-

(1) Although chlorination will greatly reduce spoilage due to contaminated cooling water it must only be used for this purpose after it has been shown that seams of normal commercial quality are being regularly produced, otherwise chlorination can be detrimental in that it may conceal defective seams which will subsequently lead to spoilage.

(2) The addition of chlorine must be carefully controlled and should only be carried out after securing the advice of water treatment technicians.

(3) Controlled chlorination of all water supplies may be useful in the prevention of off-odours and the formation of slime on certain items of plant and equipment.

A considerable proportion of the water used in a cannery is required for the production of steam for processing, or for such operations as exhausting, blanching, etc.

Few waters are suitable for use in boilers without treatment, as the impurities present in the form of mineral salts, organic matter and dissolved gases are liable to cause corrosion or deposit scale on the heating surfaces and thus reduce the efficiency of the boiler.

There are many methods used in the treatment of water, but it is not within the scope of this volume to do more than refer briefly to the principal methods ; for more detailed information the reader is referred to the several standard works on the subject of water treatment and the organisations producing water treatment equipment and chemicals.

The chief scale forming substances most likely to be present in water used in boilers are salts of magnesium and calcium. These may be divided into two groups :—

(1) Those which produce "temporary" hardness ; the bicarbonates of calcium and magnesium.

(2) Those which produce "permanent" hardness ; the sulphates, chlorides and nitrates of the above metals.

On heating, as in a boiler, the bicarbonates are decomposed giving off carbon dioxide and depositing calcium and magnesium carbonates which have a relatively low solubility ; the magnesium carbonate is further decomposed to form the hydroxide which is even less soluble than calcium carbonate.

The salts producing permanent hardness are decomposed gradually as heating proceeds, and when saturation point is reached they commence to crystallise.

It has been shown that the chief constituents of boiler scale are calcium and magnesium sulphates, carbonates, silicates and

hydroxides and all methods of water treatment aim at preventin
the formation of these salts.

There are three main methods of treating boiler feed water :—

(1) Processes which aim at precipitating the slightly solubl
calcium and magnesium salts by the addition of certai
chemicals such as sodium carbonate and lime, as in the lime
soda process.

(2) Processes which remove the salts causing hardness withou
precipitation by replacing the calcium and magnesium ion
by sodium or other suitable ions, as in the zeolite, or base
exchange process.

(3) Demineralisation by which it is possible to remove practicall
all salts.

In the lime-soda process sodium carbonate and hydrated lime ar
added to the water to be treated, whereupon the calcium and mag
nesium salts are precipitated. The process can be worked in the col
but greater efficiency is obtained if it is carried out at about 70°C
In all cases special dosing equipment is necessary if large quantitie
of water have to be regularly treated, and it is essential that sufficien
time should be allowed for the precipitated salts to settle.

A modification of this method which is particularly useful whe
water containing considerable quantities of magnesium salts has t
be dealt with, utilises the fact that in dilute solutions, such as ar
encountered in water softening reactions, sodium aluminate hydro
lyses to form a dilute solution of sodium hydroxide and a wea
suspension of aluminium hydroxide. The aluminium hydroxid
which is partly present in the form of a negatively charged collodi
suspension, readily aggregates with the positively charged magnesiu
hydroxide which is produced as a result of the addition of the lim
soda mixture. The mixed precipitate of aluminium hydroxide an
magnesium hydroxide forms large flocculent particles which tend
remove any other suspended matter and colloidal material with t
result that the removal of the calcium and magnesium salts is mo
rapidly and completely carried out than is the case when the lim
soda mixture is used without the addition of the sodium aluminat

The lime-soda process is not suitable for very soft waters, ar
phosphates are sometimes substituted for lime-soda.

The base-exchange or zeolite process produces a water with ve
nearly zero hardness, the calcium and magnesium salts being replac
by sodium salts. In the application of this method the water to
treated is passed through beds of zeolites, which are complex silicat
with a very open molecular structure characterised by the fact th

they can exchange their own metallic radicals for those of other metals when a solution of the salts of other metals is passed through them. Thus in the case of sodium zeolite, the zeolite removes the calcium and magnesium radicals replacing them by sodium, thus forming highly soluble non-scale forming salts.

The beds of zeolite become exhausted after a time and are then regenerated by treatment with a solution of common salt.

Recently a process known as demineralisation has been finding increased application in treating water where a very high degree of purity is desired. In this process which takes place in two stages, artificial base-exchange resins are used which first convert all calcium, magnesium and sodium salts into the corresponding acids, the acid solution is then passed through a second ion exchange material which has the power of absorbing dilute acids thus removing the acids and leaving a water free of all ions with the exception of certain silicates.

In some small plants the installation of a separate plant for water softening may not be justified, and a number of substances have been suggested for direct introduction into the boiler feed water the object being to precipitate the salts causing hardness in the form of a sludge instead of allowing them to form a scale on the surface of the boiler. If this method is adopted it must be based on the results of analysis of the water to be treated and in consultation with water treatment technicians, as the exact procedure will vary considerably depending on the raw water.

Apart from its use in the production of steam for processing, considerable quantities of water will be required for blanching and the preparation of brines and syrups, etc. In all these processes consideration must be given to the possible effect of the mineral content of the water on the food products being treated.

An extensive study of the effect of hard water on the canning of vegetables has been made by Bigelow and Stevenson[10] who pointed out that the salt used for making up brine should be free of calcium and magnesium compounds, they suggested 0.3 per cent of calcium as a maximum value where possible. With peas the hardness of water used in washing and rinsing was shown to have no appreciable effect on the toughness of the finished product, blanching, however, subjects the peas to the action of a hot solution of calcium and magnesium salts which if the water is very hard may affect the toughness of the final product.

Bigelow and Stevenson[10] state that the use of softened water for blanching is desirable where the total hardness of the water approaches 400 p.p.m.

Horner[11] working with dried peas has obtained analogous results

and compares the action of peas in absorbing calcium and magnesium salts with that of the zeolites used in water softening.

The toughening of certain products by calcium and magnesium salts is turned to advantage in the canning of tomatoes and potatoes and calcium chloride is added to prevent the breakdown of texture which sometimes occurs. This procedure is considered in more detail in Chapter 12.

In conclusion it must be emphasised that before embarking on any system of water treatment the advice of fully competent water engineers should be obtained supported by comprehensive analytical data of the water to be treated. By following this procedure much disappointment and unnecessary expenditure will be avoided.

Disposal of Cannery Wastes

The disposal of cannery wastes has not until recent years attracted much attention in the United Kingdom, although, in the U.S.A. where the magnitude of the problem is much greater, a considerable amount of work has been done on the subject. During the war, however, the increased output of canned and dried vegetables for the Services focused attention in this country on the effluent problem, and in rural areas where the existing systems were only designed to deal with normal domestic effluents the problem often became acute.

Some canneries are located close to large towns where facilities exist for treatment of industrial wastes, but in many cases the volume and specialised character of the waste necessitates a change in the treatment processes and the provision of additional capacity.

The most common type of pollution is caused by the discharge of wastes containing organic material either in suspension or solution.

The self-purification which occurs in streams or in a large body of water into which waste is discharged is a biological process which uses up the oxygen content of the water. If the water contains sufficient oxygen for the complete aerobic oxidation of the organic material in the waste, stable end products will be produced, the stream will not become septic and no undesirable odours will be generated. If, however, the oxygen content is not sufficient to support complete aerobic oxidation of the polluting organic matter, anaerobic decomposition will take place with the production of undesirable odours and the destruction of marine life.

The amount of oxygen necessary to prevent odours is very variable but Eldridge[12] has mentioned a figure of 2 p.p.m. and 4-10 p.p.m. for the support of marine life.

The waste will have a certain oxygen requirement for its purification; this is known as the "biochemical oxygen demand" or B.O.D., and the primary object of any waste treatment plant is to reduce the

B.O.D. of the waste to a low value before discharge into the receiving body of water.

Canneries use large quantities of water and the wastes produced are, therefore, usually large in volume. Each type of cannery produces its own characteristic waste. Meat and fish cannery wastes, for example, are characterised by a high nitrogen and fat content with a considerable percentage of the material in the colloidal state. Milk products plants produce a predominantly liquid waste containing proteins, milk sugars and fats, the bulk of the solids being in true or colloidal suspension. Fruit and vegetable canneries often produce a large volume of waste containing a high proportion of solid matter such as peelings, skins, and particles of soil as well as starchy materials which are usually in the colloidal state.

Cannery waste commonly consists of two phases, liquid and solid, and the methods used in the disposal of each phase are quite different.

Preliminary treatment in all cases usually consists in the removal of the solid phase by means of rotating or vibrating screens, and in the case of meat packing plant wastes the removal of grease in a grease trap.

Many types of screens are in use for the removal of solid particles, but regardless of the type chosen it is essential that adequate facilities such as water jets or moving brushes should be provided for the rapid removal of the accumulated solid material. The solid waste which is screened from the liquid waste should be removed as soon as possible to avoid odours and the provision of a breeding ground for vermin and micro-organisms.

The final disposal of solid wastes often presents a difficult problem and will vary with the type of material under consideration. In some cases it may be used as a fertilizer, for cattle feeding, or simply buried in the ground or burnt.

So far little work appears to have been carried out in the United Kingdom on the production of by-products from cannery wastes, but in the U.S.A. where large quantities have to be dealt with each year considerable attention has been devoted to the possibility of utilising wastes, particularly the solid phase. The utilisation of vegetable wastes has been investigated by Morris[13], while citrus wastes have been studied by Pulley, Moore and Atkins[14] and by Rosseau[15]. The utilisation of several types of cannery waste has been discussed by Wiegand[16], and the number of products which have been prepared from waste is considerable. Nealy[17], for example, has reported six products with commercial possibilities being recovered from cranberry wastes including such substances as ursolic acid, cranberry wax and cranberry oil, etc.

The treatment and disposal of the liquid portion of the cannery

waste often presents great difficulty as the volume is usually large and in many cases colloidal solutions are encountered.

The methods available for the treatment of the screened waste have been listed by Sanborn[18] as follows :—

  (1) Chemical precipitation or sedimentation.
  (2) Biological filtration.
  (3) Discharge to Local Authority treatment plant.
  (4) Land absorption.
  (5) Impounding in a lagoon.

Chemical precipitation removes suspended matter and solids in the colloidal state, and lime followed by ferrous sulphate or alum is often used for this purpose. The sedimentation of fruit and vegetable cannery wastes has been described by Dickinson[19] and considerable information on the volume, and methods of treatment of fruit and vegetable cannery waste has been given by Warrick, McKee, Wirth, and Sanborn[20].

Biological treatment reproduces the natural purification which takes place in a stream by allowing the waste, which has previously been screened, to trickle through layers of porous material covered with a growth of micro-organisms. The chief disadvantage of this process particularly in the case of plants with seasonal production is that the establishment of a satisfactory growth of bacterial flora takes some time and if full efficiency is to be obtained the flow through the filter must be maintained at a steady rate. A pilot plant of this type for the treatment of fruit and vegetable cannery wastes has been described by Dickinson[21].

In some cases canneries can take advantage of Local Authority treatment plants, but screening and sometimes chemical precipitation before discharge will in most cases be necessary.

In other cases running the screened wastes over land may be permissible, but care must be taken to avoid the production of offensive odours or the pollution of adjacent water supplies by percolation of the waste through the soil. Sanborn[18] mentions the use of furrows as receiving channels for the effluent, thus providing a greater surface area for absorption.

Finally, mention must be made of the practice of impounding screened wastes in lagoons, a process which has found considerable application in the U.S.A. In this process the waste is run into lagoons and allowed to remain until sufficient decomposition of the organic matter has taken place to permit its safe discharge. It is usual to add sodium nitrate to the lagoons to reduce offensive odours and to encourage the growth of organisms which will oxygerate the water

The use of lagoons has not as yet found much application in this country, one of the chief difficulties being to find a suitable location; where a suitable site is available, however, the method is a relatively cheap and easy system of disposing of the liquid portion of cannery waste.

The foregoing summarises the most important points occurring in the disposal of cannery waste, but for more details the reader is referred to the several works on the subject particularly that of Eldridge[12] and the bulletins[20, 22], published by the National Canner's Association of America.

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THE EXAMINATION AND PREPARATION O[F] RAW FOOD MATERIALS FOR CANNING

THE examination and preparation of raw materials for canning ar[e] both operations which, if properly carried out, contribute a grea[t] deal to the quality of the finished product.

Under present conditions it is not always possible for the canne[r] to exercise much choice in the selection of his raw materials, bu[t] this in no way relieves him from the responsibility of ensuring tha[t] the raw materials he does receive are satisfactory for the purpose fo[r] which they are intended. Restriction of supplies does in fact mak[e] regular examination and checking all the more important as a mea[ns] of preventing subsequent trouble through the use of materials fro[m] unusual sources and which may depart from accustomed standard[s].

The Examination of Raw Materials

In addition to the raw food materials used in the cannery suc[h] ancillary items as cans, labels, adhesives, lacquers and many othe[r] should all be subjected to examination from time to time to ensu[re] that there is no departure from specification. The methods used i[n] the examination of tinplate, cans, and lacquers are indicated i[n] Chapters 2 and 3, and attention is confined in the present Chapter t[o] the examination of the raw food materials.

A high proportion of the work in connection with the examinatio[n] of raw materials will naturally devolve on the laboratory and in man[y] cases it will be the function of the laboratory to assist the purchasin[g] department in drawing up specifications against which purchases v [ill] eventually be made.

It is not intended in this Chapter to deal with the normal method[s] of food analysis, but rather to confine attention to certain aspects [of] the examination of raw materials which are of special interest to th[e] canning industry. For information on the technique of food analys[is] the reader is referred to such standard works as those by Cox[1], an[d] by Winton and Winton[2].

In the canning industry one of the most important consideration[s] is the condition of the raw material with respect to contaminatio[n] with spoilage organisms. Sterilising processes are based on th[e]

assumption that good quality fresh raw material will be used, consequently any variation in freshness and quality may affect the validity of the calculated process. In the examination of raw materials, therefore, information on the extent of contamination with micro-organisms is of paramount importance.

All raw materials add in some degree to the total number of micro-organisms present in the closed can, but very little trouble is experienced with the non-heat resistant organisms provided processing is properly carried out and the degree of contamination does not reach abnormal values.

During the last few years, however, it has been shown that certain raw materials may be carriers of considerable numbers of heat resistant organisms, particularly those in the thermophilic group, and considerable attention has, therefore, been devoted to the examination of the raw materials concerned ; in some cases maximum limits have been suggested for the number of spoilage organisms, materials containing quantities in excess of the maximum being regarded as unsuitable for canning purposes.

Thermophilic organisms have been found in a wide range of raw materials, including sugar, starch, spices, milk powder, flour, colouring agents, etc. Soil has also been shown to be a carrier of these organisms, and it is, therefore, of vital importance to prevent the entry of soil into the canning plant.

Sugar was the first material of importance to the canning industry known to be liable to contain thermophiles ; Cameron, Williams and Thompson[3] in studying the spoilage of canned corn found that the trouble was caused by thermophilic anaerobes carried in the sugar used as a sweetening agent.

The origin of the thermophiles in cane sugar has been studied by many workers including James[4]. Cameron[5], Cameron and Bigelow[6], and Cameron and Yesair[7], while both Calton[8] and Hall[9] have shown that similar contamination occurs in beet sugar.

The results of the above workers, and others, show that the development of thermophilic organisms in sugar takes place during refining. Millstein, Tobin and McCleskey[10] have also shown that the raw syrup often contains a large number of mesophiles, most of which are removed during clarification. In the case of thermophiles, however, it was found that the raw syrup contained relatively few organisms, but that they tended to build up during crystallisation.

A comprehensive review of the occurrence of micro-organisms in sugar, molasses, and other sweetening agents has been given by Tucker and Pederson[11], and work in sugar refineries has shown that by extra filtration and crystallisation the number of organisms present may be considerably reduced.

As a result of work by the bacteriologists of the National Canner's Association of America, limits for the contamination of sugar for canning were established and first published by Bigelow[12].   These standards which have been revised from time to time in the light of new information are at present as follows :—

Total Thermophilic Spore Count : For the five samples examined there shall be a maximum of not more than 150 spores and an average of not more than 125 spores per 10 grams of sugar.

Flat-Sour Spores : For the five samples examined there shall be a maximum of not more than 75 spores and an average of not more than 50 spores per 10 grams of sugar.

Thermophilic Anaerobes : These shall be present in not more than three of the five samples, and in any one sample there shall not be more than four positive tubes.

Sulphide-Spoilage Spores : These shall be present in not more than two of the five samples, and in any one sample to the extent of not more than five colonies per 10 grams.

The technique of examining sugar for thermophilic organisms been fully described by Cameron[13] and also by Baumgartner[14] as follows Cameron's methods.

Little work has been published in the United Kingdom subject of sugar for canning, although, McMaster[15], and Baie have examined a number of samples of sugars refined in Great [16] and have found them to contain significant quantities of thermo

An examination of many samples of sugar refined in Britas. also undertaken by Gillespy[17], and he found that a consi as proportion of the samples were unsuitable for canning due le presence of thermophiles. Experiments with processed peas he that the use of contaminated sugars rendered normal ped ineffective. Similar work by Cameron and Yesair[18] using ses demonstrated the importance of using thermophile free suga as results are shown in Table VIII. eir

It will be seen from the foregoing paragraphs that the exal of sugar used in canning is an important factor in the preven spoilage of canned goods, particularly those which are like of consumed or stored in warm climates. e

The occurrence of thermophiles in starch has attracted less a than in the case of sugar, but results obtained by Owen and n and later by Clark and Tanner[20] have shown that starch may [19] considerable numbers of thermophilic organisms, the last twen having found as many as 325 flat-sour organisms per 10 grs starch. of

TABLE VIII

Spoilage in No. 2 Cans of Corn Due to the Presence of Thermophilic Organisms in Sugar

(Cameron and Yesair)

Length of process at 250° C.	Per cent spoilage		
	No sugar	Sugar A	Sugar B
Mins.			
70	0	0	95.8
80	0	0	75.0
90	0	0	54.2

Sugar A had a "flat sour" count of 60 spores per 10 grms.
Sugar B had a "flat sour" count of 2,500 spores per 10 grms.

The same standards as for sugar have been suggested by Clark and Tanner[20] for starch, and these authors also describe modifications of Cameron's method for the examination of sugar to overcome the difficulties encountered due to the tendency of the starch to thicken when heated. The same authors also report that, although all three groups of thermophilic organisms have been found in starch, thermophilic anaerobes are the most common.

The control of micro-organisms present in starch by modification of the normal bleaching technique, which uses chlorine, has been suggested by McFarlane and Hall[21], while according to Cameron[22], the problem of starch contamination in the U.S.A. appears to have been largely overcome by the producers.

Another raw material used in canned foods which may contain significant quantities of micro-organisms is spice. The possibility of spices causing spoilage when incorporated in canned foods was first given prominence by Jensen, Wood and Jansen[23] in relation to their use in canned spiced chopped ham.

A wide range of spices were examined by Yesair and Williams[24] and they found that black pepper was the most heavily contaminated the total counts on seven samples ranging from 1,200,000 to 16,300,000 organisms per gram, although, the incidence of thermophilic organisms was fairly low. Fabian, Krehl and Little[25] found up to 67,000,000 organisms per gram in spices purchased in the open market, but no attempt was made to estimate the number of thermophilic organisms in this figure.

Yesair and Williams[24] carried out extensive tests on methods of sterilising spices, and found that moist heat was effective in sterilising black pepper as also was a method patented by Griffith and Hall[26] which used ethylene oxide, after first subjecting the spice to a high

vacuum. The disadvantage of this method, however, is the fact that about two and one half hours contact is required as compared with the 15 minutes used by Yesair and Williams[24] with steam at 15 lbs./ sq. in. pressure.

A suggested method for the examination of spices put forward by the American Public Health Association's Committee on the Micro-biological Examination of Foods is described in detail by Baumgartner[14], but no standards have as yet been adopted as in the case of sugar.

Milk powder, which is used in many products, has been found to contain thermophiles and prolonged preheating of the milk prior to drying has been suggested by Higginbottom[27] as the cause of the high counts sometimes obtained.

Samples of dried milk have been examined for thermophiles by Sorensen[28] using the method evolved by the National Canner's Association for sugar. Certain modifications in technique were, however, found necessary in order to overcome the tendency of milk powder to form very viscous solutions and to froth on boiling. Difficulty was also encountered in making plate counts owing to the occurrence of undissolved specks of powder, this was overcome by adding N/60 sodium or lithium hydroxide solution to the culture media.

The highest count obtained for thermophilic organisms was 40,100 organisms per gram, but many of the samples examined gave quite low values. Milk powder, however, frequently forms a consider-able proportion of the can contents and even relatively low counts may, therefore, have some significance.

Although it has been known for many years that soya beans and soya flour often contain considerable numbers of micro-organisms, it is only recently, largely due to their increased use in chopped meat packs as extenders and binders, that any great attention has been paid to the examination of these materials. Jensen and Hess[29] report experiments using meat mixtures containing 20 per cent of soya flour with over 100,000 spores of a gas-forming thermophilic anaerobes per gram, which showed that the thermophilic spoilage which took place could be prevented by the addition of $3\frac{1}{2}$ per cent of salt and a curing mixture consisting of $2\frac{1}{3}$ ounces of sodium nitrate and $\frac{1}{8}$ ounce of sodium nitrite per 100 lb. of meat.

The examination of wheat flour, corn flour and several other types of flour by Yesair and Reed[30] showed that the percentage of satis-factory samples was fairly high, the authors stated, however, that the regular examination of such materials was desirable in order to avoid trouble caused by the use of an occasional unsatisfactory sample.

In a criticism of the methods and standards adopted in the examin-ation of raw materials for thermophiles Knock and Baumgartner[31]

point out that the actual heat resistance of flat sour spores found in certain raw materials, such as sugar and flour, is not taken into consideration when assessing the suitability of the raw material for use in canning, and they suggest that flat sour spores should be sub-divided into two classes ; those which survive a heat treatment approaching that which will be given during processing and are, therefore, potentially resistant to processing ; and those spores which will not survive heat treatment and are therefore of no significance in causing spoilage.

The same authors[31] also point out that in the formulation of existing standards for raw materials no consideration has so far been given to the varying amounts of the raw materials used in the final pack and they suggest that standards should not be based on the number of spoilage organisms present in the raw material, but rather on the number of organisms which the material will carry into each can in the particular pack under consideration.

The above criticism is met in some measure by the procedure adopted in some canneries of examining the finished product before processing in order to ascertain the number of heat resistant organisms actually present in the filled can instead of examining the raw materials *per se*.

The preceding paragraphs clearly indicate the importance of examining all raw materials to ensure that they are suitable for the purpose for which they have been purchased, and a strong case can be made for the adoption of a regular schedule for the bacteriological control of all raw materials.

Reference is made in Chapter 8 to the work of Lang[32] in which he found that the empty can was a possible source of micro-organisms. Similar work by Fellers[33] showed counts up to 162,000 organisms per can, while thermophilic organisms were relatively common. It is, therefore, important that cans should be washed before use and that periodical examinations should be made for micro-organisms, not only of the cans themselves, but also of the can store to ensure that no source of heavy infection exists.

So far in this Chapter the emphasis has been placed on the import-ance of the bacteriological examination of raw materials, there are, however, other aspects of raw material examination which must be considered.

Contamination of raw materials with metals and salts of metals is discussed in Chapter 10, and nothing further need be said on this subject other than to emphasise the importance of the regular examination of raw materials, particularly where a change in the source of supply has been made.

The action of sulphur compounds in accelerating the corrosion of

tinplate has been referred to in Chapter 3, and the examination of raw materials such as sugar which may contain sulphur compounds is, therefore, desirable. The method suggested by Bryan[34] which is similar to the Gutzeit test for arsenic may be conveniently used for this purpose.

The determination of the porosity of tinplate has already been dealt with in Chapter 3; an additional method which can be used as a routine test has been suggested by Morris[35] in which rings of glass of about 3 inches internal diameter and $\frac{1}{2}$ inch in thickness are clamped to samples of the tinplate to be examined, a known volume of standard hydrochloric acid is added to the reservoir so formed and left for a definite time, the iron and tin dissolved by the acid can then be determined. If a standard quality of tinplate is used as a control a measure of the quality of the sample under test can be obtained.

A raw material which requires particular care in examination is milk, whether it is to be used for the manufacture of condensed or evaporated milk, or as an ingredient in some other pack. The quality of milk is to a large extent determined by conditions on the farm where it is produced, and it is necessarily there that quality control commences. It is essential, therefore, to arrange for the regular inspection of milk as it is received at the cannery in order to ensure that no departure from recognised standards takes place and so that the producer may be advised immediately his milk shows any signs of falling off in quality. The examination of milk for condensing or evaporation has been fully dealt with by Hunziker[36] to whose work the reader is referred for further details.

Preparation of Raw Materials

The preparation of raw materials for canning is not always given the care and attention it merits, with the result that good quality raw materials are sometimes wasted and the quality of the final pack is lowered.

In the present Chapter the preparation of raw materials is regarded as covering all operations up to the filling process and, therefore, includes grading for quality and size. Few comprehensive accounts have been published in the United Kingdom of the preparation of food for canning but there have been numerous works such as those by Bitting[37], Cruess[38], Jarvis[39], and others which give details of the methods used in the U.S.A. It is not, therefore, proposed to consider the many methods adopted for individual raw materials, but rather to confine attention to certain of the main operations.

Fruit and Vegetables. These raw materials have many points in common as far as their preparation is concerned and may, therefore, be considered together. In most cases fruit and vegetables will be

contaminated to some extent with soil which, as previously stated, is a frequent carrier of spoilage organisms. The first operation, therefore, in the preparation of these materials is usually the removal of any adhering soil.

In some cases, however, additional preliminary treatment is required as, for example, in the case of peas which must be removed from the pods, a process known as vining. One type of vining machine is shown in Fig. 48 and consists of a revolving perforated metal cylinder along whose axis runs a shaft to which beaters are attached. The cylinder revolves slowly while the shaft carrying the beaters revolves at a relatively high speed. The peas are shelled by impact against the beaters and then fall through the perforations in the outer metal cylinder. The vines are carried through the viner by the beaters which are set in such a manner that they act as a conveyor.

FIG. 48. Steel-framed vining machine.
(*Courtesy Chisholm-Ryder Co., U.S.A.*)

After any preliminary treatment such as vining it is normal practice to carry out a further cleansing operation by subjecting the fruit or vegetables to an air blast and/or to screening. By this means a great deal of loose and light material is removed and much work is saved in the subsequent washing and picking operations.

The washing operation which occurs at some stage in the preparation of most products is of considerable importance. The process may be carried out in several different ways the choice of method depending to a large extent on the product to be washed. Some products will stand up to a more vigorous treatment than others, and the method, therefore, varies accordingly.

In the washer illustrated in Fig. 49, which is particularly useful in washing fruits and berries such as strawberries, raspberries, cherries, plums, apples, etc., the fruit is placed in a hopper and then carried
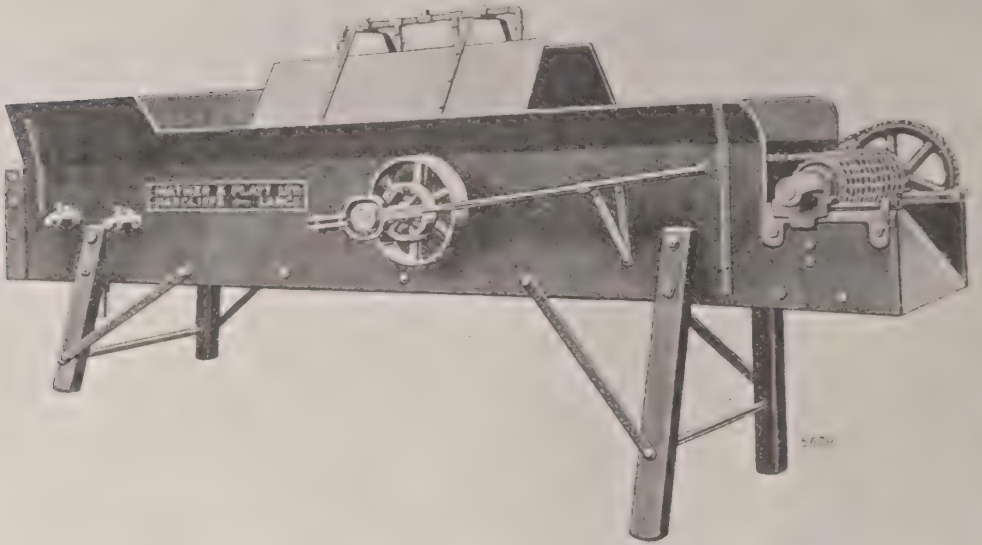
FIG. 49.   Fruit and berry washer.
(*Courtesy Mather and Platt Ltd.*)

forward on a perforated belt. Water is forced through the perforations in the belt by means of a paddle wheel the fruit being gently agitated so that it receives a thorough washing. The fruit is finally drained before discharge.

For products which can stand more vigorous handling such as peas, beans and similar products rotary washers are used which in some cases also remove light foreign materials by flotation. The type illustrated in Fig. 50 has a riffle board section which first traps stones and other foreign matter. The raw material to be washed then passes through a float section where the light matter which floats is removed from the surface by means of a screw conveyor. Finally the material to be washed passes through a revolving screen where water sprays give a final wash. A washer of this type will handle many products such as peas, beans, cherries, etc. as it is possible to obtain screens with various sizes of perforation to suit the product being washed.

In handling root vegetables, potatoes, and other products, which are usually heavily contaminated by soil, it is desirable to arrange a preliminary washing before the raw material is taken into the preparation room proper and thus avoid bringing soil into the cannery.

During the war period the practice of size grading which was being introduced into canneries in Great Britain under the National Mark scheme was largely abandoned, but with the coming of peace and

the resumption of competitive trading, size grading is once more being introduced.

With fruits and other delicate products grading by hand is sometimes necessary in order to avoid undue damage to the product, but mechanical graders are more efficient and can handle larger outputs. These mechanical graders may consist simply of a vibrating screen or series of screens with holes of various sizes depending on the product to be graded, all units of the same size fall through a particular sized screen and are collected and packed accordingly. In some graders the large sized units are removed first and then the next smallest, etc. In other types of graders the small sized units are removed first and then the next largest, etc. Cruess[38] points out that this second method is
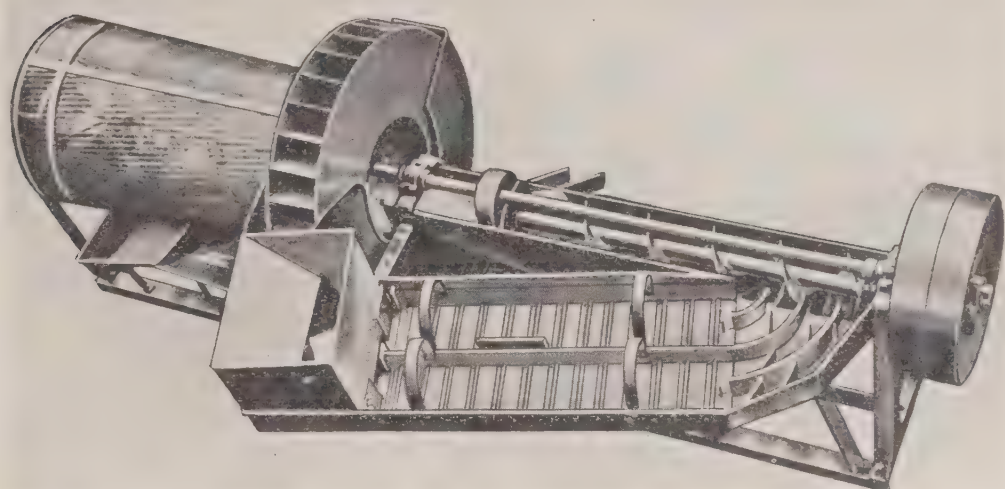
FIG. 50. Rotary washer with riffle board for the removal of stones and other foreign matter. (*Courtesy Mather and Platt Ltd.*)

considered objectionable by some as the larger units, which by virtue of their size are most liable to be damaged, are subjected to more agitation than the smaller units on which the effect of agitation is less marked.

When products which can stand up to more vigorous handling are being packed rotary graders can be used. These graders consist of a revolving screen split up into a number of sections appropriate to the number of grades into which the material is to be divided. Each section has perforations appropriate to the size of each grade. The raw material is fed into the rotating grader the smaller units dropping through the first screen section and so on until the largest units drop through the last section.

Instead of using a cylindrical screen a patented modification known as the "Cloverleaf" type of screen is sometimes used. This is illustrated

in Fig. 51 and it is claimed that the effect is almost the same as if the material was graded in four very small drums instead of one fair sized one.

In the U.S.A. the size grading of many products is an established practice, for example, seven grades of peas are recognised as standard. These grades vary in steps of 1/32in. from 9/32in. to 14/32in. in diameter the last grade including all peas over 14/32in. Grading of this highly mechanised type can only be carried out with products which are fairly regular in size and sufficiently firm to stand up to the handling involved.
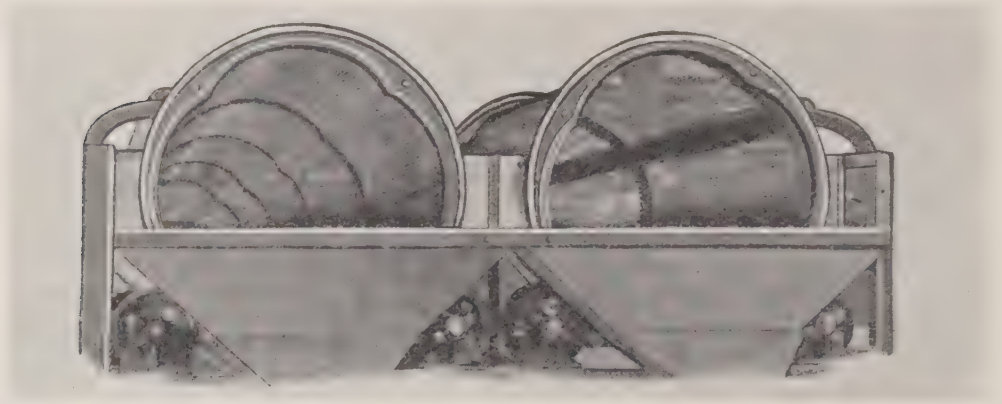
Fig. 51.   End view of twin reel pea grader showing "Cloverleaf" screens.
(*Courtesy Mather and Platt Ltd.*)

At some stage in the preparation of almost all products it is customary for the food being prepared to be subjected to visual inspection to remove any sub-standard material which has escaped elimination by mechanical grading and sorting. The picking tables, on which this work is carried out usually consist of a belt conveyor which carries the product to be examined past inspectors who pick out any unsuitable material. It is important that these inspectors clearly understand the minimum standards permitted and that careful supervision is exercised to ensure that these standards are adhered to at all times.

In modern plants the picking table is usually placed immediately before the filler as this reduces to a minimum the possibility of any unsatisfactory material being included after inspection.

An important consideration in the choice of picking tables is the material from which the conveyor belt is constructed. Stainless steel is to be preferred with white rubber as a second choice. The use of dark coloured material is objectionable as it does not reveal dirt and therefore discourages the frequent cleaning which is so essential if build-up of spoilage organisms is to be avoided.

In some cases, particularly with vegetables and some fruits, a skin or outer covering must be removed before the food can be packed. This operation varies considerably in difficulty, the skins of tomatoes, for example, are easily removed by scalding and subsequent cooling, while potatoes require much more vigorous treatment.

The efficiency of this peeling operation is of considerable importance as pieces of skin not only spoil the appearance of the pack, but may also give rise to spoilage due to the fact that they may carry a considerable number of spoilage organisms. This is particularly true in the case of root vegetables and potatoes.

Peeling processes range from hand peeling to completely mechanical peeling, an operation which may be divided into five types as follows :—

     (1) Abrasion peeling (Batch and Continuous).
     (2) Lye peeling (Dilute and Concentrated).
     (3) Flame peeling.
     (4) Brine peeling.
     (5) Steam peeling.

Abrasion Peeling. This process may be carried out in batches or continuously, and is particularly useful for peeling potatoes, carrots, beets, and other products which can withstand a certain amount of rough handling.

Batch type peelers as illustrated in Fig. 52 consist of a chamber, lined with carborundum or other abrasive, in which the material to be peeled is placed. The bottom of the chamber consists of a disc, also covered with abrasive material, which revolves, thus causing the contents
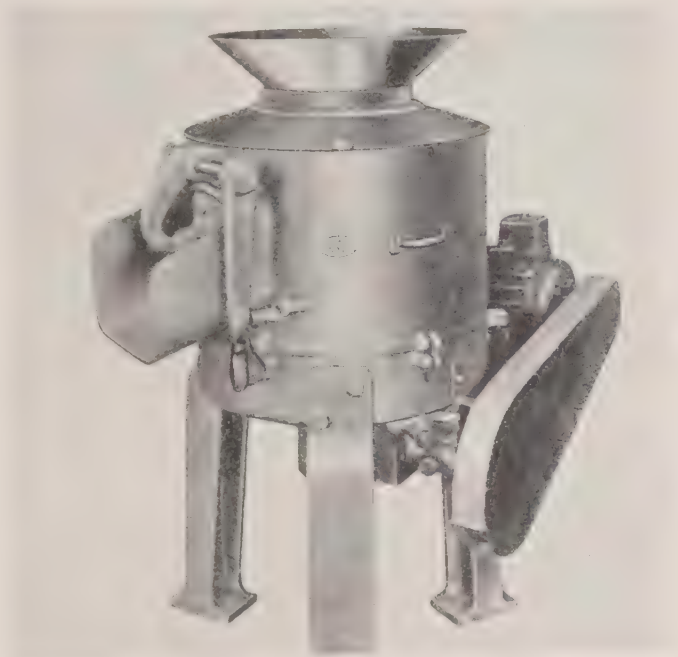

Fig. 52. Batch type abrasion peeling machine.
(*Courtesy William Brierley, Collier and Hartley Ltd.*)

of the peeler to rub against the bottom and sides of the chamber thereby removing the skin. A machine of the type illustrated deals with batches of 50 60 lbs. at a time and has an output of about 1,000 lbs. per hour.

Suitably modified this type of machine may be used for snibbing gooseberries or for removing the skin from new potatoes.

Where outputs higher than the above are required it is customary to use continuous abrasion peelers, an example of which is illustrated in Fig. 53. This machine consists of a series of compartments at the bottom of which are a number of rollers covered with abrasive material. The product to be peeled is fed into a hopper at one end of the machine and passes over the rapidly rotating rollers which remove the skin. The apertures joining the compartments are so arranged
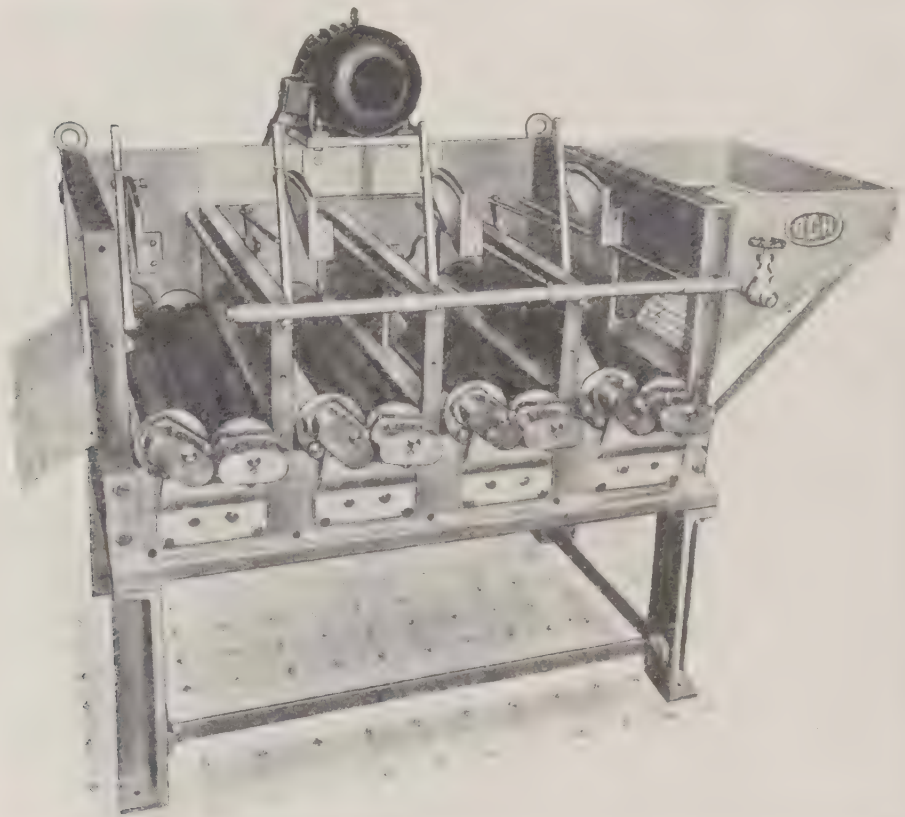
Fig. 53. Continuous abrasion peeling machine with side removed to show arrangement of peeling rollers.
(*Courtesy William Brierley, Collier and Hartley Ltd.*)

that the raw material has to follow a tortuous path through the machine thus ensuring that all surfaces to be peeled come into contact with the rotating rollers. The output is of the order of 2 tons per hour. During the operation water flows continuously through the machine washing pieces of skin and other debris into a trough below the rollers.

Abrasion peeling consists essentially of grinding away the surface of the material to be peeled until the surface covering or skin is removed.

The process, therefore, entails a good deal of waste or, alternatively, if peeling is reduced to a minimum the amount of hand trimming involved is considerable. This is particularly true for products which are of irregular outline. The percentage of waste varies greatly with the material to be peeled, it may be as high as 45 per cent, but an average value would be about 25-30 per cent.

Lye Peeling. This method is widely used for the peeling of fruit and vegetables and is capable of giving very satisfactory results.

The process consists of passing the product to be peeled through a bath of sodium hydroxide solution, or "lye" as it is usually called.

The first patent on the use of lye was that of Thomson[40] which revealed the use of a lye bath for the peeling of certain fruits. A later patent by Dunkley[41] disclosed the use of alkali sprays, while Taylor[42] used a bath containing common salt and sodium bicarbonate in boiling aqueous solution.

Lye baths are now used for a variety of products ranging from peaches to potatoes, and the process offers a very flexible method which can be adapted to a wide range of conditions by simply altering the concentration, the temperature of the lye solution, and the time of immersion.

The concentration of the lye solution used depends on the type of product being treated. Slightly under-ripe fruit, for example, requires a more concentrated solution than fruit in a fully mature condition. Cruess[38] mentions a concentration of 1.5-2 per cent sodium hydroxide as being used for fruit such as peaches, while Lankler and Morgan[43] describe the use of a 10 per cent solution for such fruit as pears, apples, etc. The temperature of the lye bath is usually maintained near its boiling point which will, of course, vary with the concentration of the bath ; times of immersion vary from $\frac{1}{2}$ to 5 minutes.

Various devices have been described from time to time for the control of the strength of the lye solution, Cruess[38], for example, describes a method depending on the change in conductivity of the solution, magnetic valves automatically admitting fresh lye as required. In many cases, however, the addition of the lye is left to the judgment of the operator who keeps a close watch on the material coming out of the peeler.

The equipment used for lye peeling is usually quite simple, consisting of a tank to hold the lye, and some means of transporting the material to be peeled through the solution such as a perforated conveyor belt or perforated inclined rotating cylinder. In some cases lye sprays are used, and these serve to agitate the material and thus ensure that all surfaces come into contact with the lye.

In all types of lye peeling the loosened skin is finally removed by washing with jets of water or by tumbling in a rotary washer. The

removal of all traces of the lye is important otherwise gelatinisation and browning of the treated material may occur.

Efforts have recently been made to increase the efficiency of lye peeling by the addition of wetting agents to the lye, Olsen[44], and more recently, Lankler and Morgan[43] have obtained satisfactory results using sulphonated compounds.

For the very rapid removal of the skins of potatoes Mazzola[45] describes the use of concentrated lye solutions containing up to 53 per cent caustic soda and boiling at temperatures up to 300°F. It is claimed for this method that peeling is speeded up and wastage reduced.

Lye peeling not only increases output, but it also avoids undue wastage of raw material such as may occur in hand or abrasion peeling. Cruess[38], for example, states that in peeling peaches a loss of 12 per cent occurs in lye peeling compared with 20 per cent in hand peeling.

Flame Peeling. This process has found its widest application in the peeling of potatoes for canning, dehydration, and other processes where large quantities of peeled potatoes are required.

One application of the process which has been protected by patents[46] consists of passing the previously cleaned potatoes through a furnace heated by gas jets, the surface of the potatoes attains a temperature of about 1,750°F., and the thin outer skin blisters. These blisters then break and the outer skin adheres to the potato in the form of small bran-like flakes. These are finally removed by a combination of water jets and friction from fabric covered rollers.

The furnace itself is about 2 ft. long and the potatoes are conveyed through it by means of revolving corrugated rollers, each potato remaining in the furnace for about seven seconds.

The advantages claimed for this process are that peeling loss is low, and that better quality peeled potatoes are produced only requiring the removal of eyes.

Brine Peeling. This process uses a saturated solution of common salt, the solution is maintained at its boiling point and the material to be peeled is immersed in it for a given time which varies with the type of product being treated. The softened skins are then removed by high pressure water jets.

The advantages claimed for this method are that the cost of the solution is lower than for lye peeling, that there is no personal hazard as is the case with lye, and with many products salt carry over is not detrimental.

Steam Peeling. This method is carried out both in batches and continuously, and although a fairly recent development has already found considerable favour for peeling potatoes.

The operation of a batch type steam peeler has been described by Mazzola[47]. The steaming unit consists of a closed vessel in which the material to be peeled is subjected to the action of steam under pressure for about $1\frac{1}{2}$ to 2 minutes, the pressure being about 80 lb./sq. in. After steaming, the raw material is discharged from the steam chamber and drops on to a conveyor which passes it to the peeling unit which is somewhat similar to a continuous abrasion peeler except that the abrasive covered rolls are replaced by rough rubber rolls which remove the loose peel or skin, the process being aided by jets of water.

A unit of this type is shown in Fig. 54. In this particular example the steam chamber rotates at about 2 R.P.M. and internal baffles are provided to mix the contents during rotation.
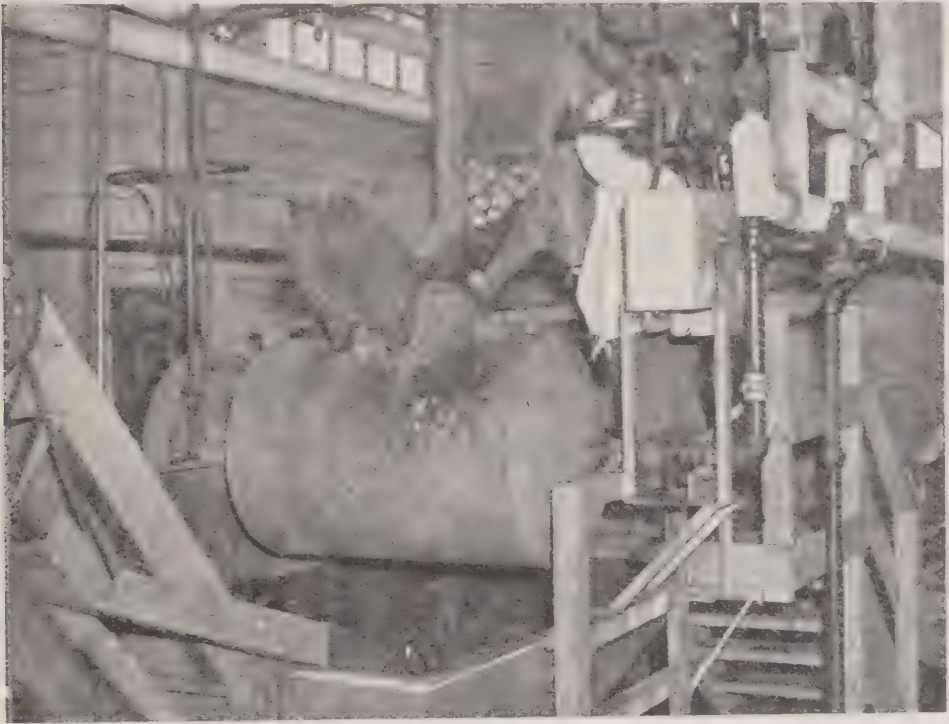
FIG. 54. Continuous steam peeling unit with revolving steam chamber.
(*Courtesy The Pfaudler Co., U.S.A.*)

Continuous steam peelers usually consist of a screw conveyor, which passes the product to be peeled through the body of the peeler where it is subjected to steam pressure. An important part of the design is the construction of the inlet and outlet valves which in most cases are similar to those used in continuous pressure cookers and coolers. Similar auxiliary equipment to that used in batch type steam peeling for the removal of the loosened peel is required in addition to the steaming unit.

There is considerable variation in the efficiency of the various methods of peeling described above, an analysis of these efficiencies for potatoes has been given by Mazzola[47] as follows :—

				Percentage Recovered
Abrasion peeling, poor stock	..	..	..	66.8
Abrasion peeling, good stock	..	..	..	69.7
Steam batch peeling	..	..	..	73.8
High temperature lye peeling	..	..	..	85.0
Brine peeling	..	..	..	53.6

The author emphasises that the above figures, which are for the preparation of potatoes for dehydration, include all losses in addition to the peeling and trimming losses, but as losses in other stages are the same the figures give a measure of the relative efficiencies of the peeling and trimming processes.

In addition to the methods described above there are a number of ingenious machines for dealing with irregular products such as pears, apples, etc., but where possible chemical peeling by lye treatment is to be preferred, as the process is relatively unaffected by variation in shape and the loss of raw material is reduced to a minimum.

Blanching. This process is a most important operation in the preparation of many vegetables and some fruits. It consists of heating the raw material in steam or hot water for a relatively short period of time.

The advantages gained by this process have been detailed by Adam and Horner[48] as follows :—

(1) The raw material is cleaned and bacterial infection is, therefore, reduced.

(2) Enzymes are destroyed and undesirable changes, such as browning, are retarded.

(3) The gases occluded in many products are expelled and excessive internal pressure in the cans during processing is therefore avoided.

(4) Blanching causes shrinkage of the raw material and also a certain amount of softening. It is, therefore, possible to pack a greater weight of material into a given volume after blanching.

(5) In some cases the flavour and colour of the product are improved.

It will be seen from the above that blanching offers a number of important advantages. There is, however, one serious disadvantage, particularly with hot water blanching, and that is the loss of nutriments which occurs due to leaching by the blanching water.

Many workers have investigated this loss of nutriments including Magoon and Culpepper[49], Horner[50], Clifcorn and Heberlein[51], and Adam[52]. The consensus of opinion definitely favours steam blanching as a means of avoiding undue loss of nutriments, but practical difficulties have prevented a wide adoption of the process, and hot water blanching is still the method most used.

The physical effects of blanching both by hot water, and by steam have been investigated by Adam and Stanworth[53], among other things they concluded that it was possible to pack 6 per cent more vegetables into a can if they were blanched and that unblanched vegetables showed an appreciably greater headspace than was the case with blanched vegetables.

A comparative study of the relative merits of steam and water blanching has been made by Melnick, Hochberg and Oser[54] who found that hot water blanching was more effective in destroying the enzymes in green beans than steam blanching, but that while loss of nutriments was insignificant during steam blanching, hot water blanching caused an appreciable loss.

Hot water blanching may be carried out either in batches or continuously, the latter being the most widely used method except for very small outputs. Blanching in batches is carried out by placing the material to be blanched in a perforated metal basket then immersing in a vessel of boiling water for a given length of time depending upon the product being blanched. This method is, however, only economical for very small outputs.

Continuous blanching has been sub-divided by Schmid[55] into three categories as follows :—

(1) The immersion or conveyor type employing either a screw or chain conveyor.

(2) The hydraulic type, wherein the product is conveyed in hot water through numerous lengths of pipe by a circulating pump and the aid of steam jets.

(3) Blanching in the can, wherein the product to be blanched is placed in the can after which hot water is added and the whole heated, followed by drainage of the blanching water.

The immersion blancher is that most used, an example of this type being illustrated in Fig. 55.

The product to be blanched is fed into one end of the blancher and becomes immersed in water heated to the blanching temperature, the product is conveyed through the blancher by the screw conveyor, the rate of travel being adjusted to give the required blanching time.

Temperature control on all types of blanchers is most important if

uniform results are to be obtained. It will be appreciated that the inlet end of the blancher will tend to be at a lower temperature than the rest of the blancher due to the entry of cold raw material. It is convenient, therefore, if the temperature controllers are so arranged that the inlet section is controlled separately from the remainder of the blancher so that additional heat may be supplied to this section to compensate for the cooling effect of the incoming raw material.
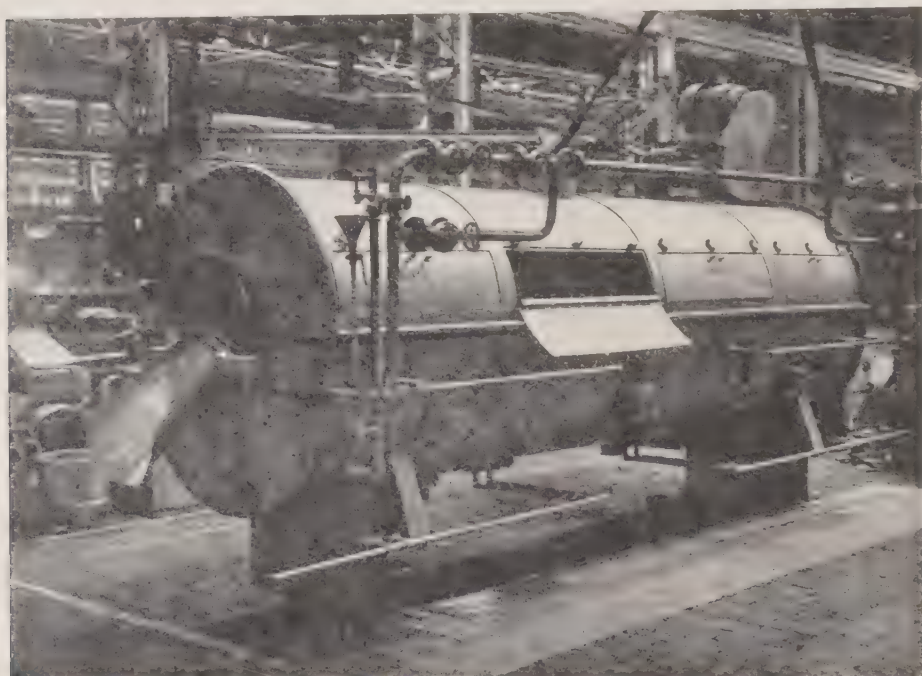

FIG. 55. Continuous water blancher.
(*Courtesy Mather and Platt Ltd.*)

This can be accomplished if two temperature controllers are used one at each end of the blancher as suggested by Schmid[55] and illustrated in Fig. 56.

The automatic control of blanching has also been discussed by Porter[56] who mentions the following advantages to be expected from the installation of automatic control :—

(1) Temperatures are held within close limits, thereby avoiding under or over-blanching.
(2) Wastage of steam by excessive heating is avoided.
(3) Manual adjustments of the steam valves are eliminated.
(4) If recording instruments are combined with the controllers a permanent record of the blanching process is obtained which may be of considerable value in checking any departure from normal technique.

In the second type of blancher the material to be blanched is introduced with hot water into a series of pipes which are heated by steam. A blancher of this type is illustrated in Fig. 57. This "pipe" blancher, as it is sometimes called, is particularly suitable for blanching products such as peas. It is claimed that this method of blanching permits a close control of the process, and also that the blancher can be easily sterilised, thus avoiding the accumulation of spoilage organisms which may occur in the standard type of blancher.

The third method of blanching described by Schmid[55] does not seem to have found wide acceptance owing to the amount of handling involved and the draining operation which is necessary.

Steam blanching like hot water blanching may be carried out in batches or continuously, but continuous blanching is usually preferred.

The mechanical difficulties in constructing a continuous steam blancher are somewhat similar to those encountered in constructing a continuous steam pressure peeler, and continuous steam blanchers, therefore, have in most cases followed the same lines of development.

An ingenious departure from conventional lines is the combined blancher, peeler, and cooker patented by McBean[57] and described by Stateler[58]. This unit consists of a steam pressure tube equipped with steam inlets, vents and pressure gauges through which a series of pistons spaced at regular intervals are drawn. The spaces between the pistons, which have a capacity of 0.8 cu. ft., function as small retorts while the pistons are in the pressure tube. This blancher has a capacity of 5 to 7 tons per hour depending on the product being blanched.
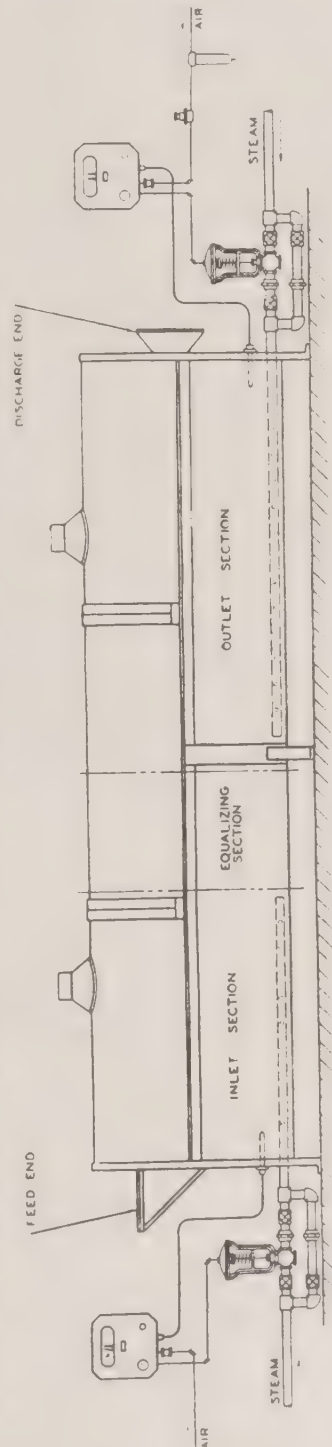

Fig. 56. Diagrammatic view of steam blancher showing method of temperature control.
(*Courtesy Taylor Instrument Co.*)

Reference has already been made in Chapter 5 to the effect of hard water used in blanching on the toughness of vegetables, particularly peas and beans, and little more need be said except to point out that an additional advantage of steam blanching is that any trouble of this kind is avoided.
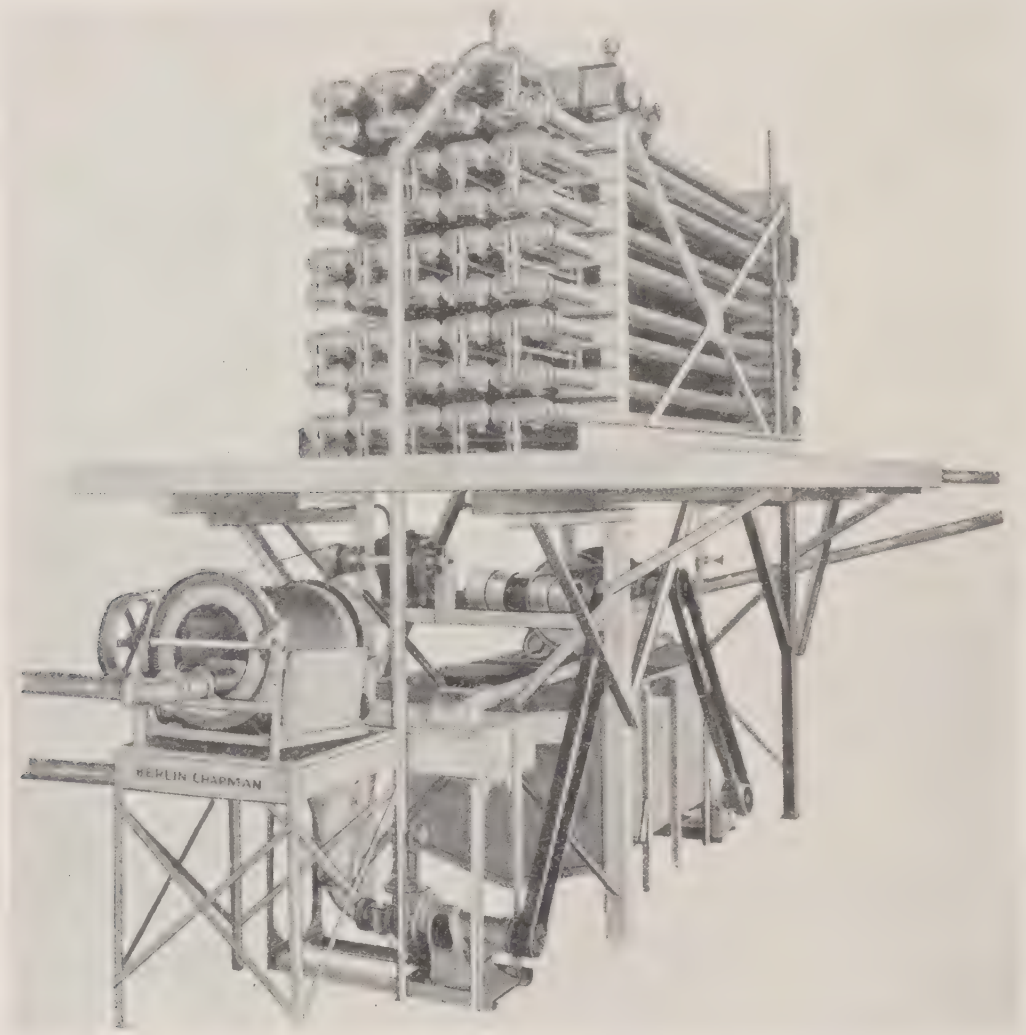

Fig. 57.   Continuous pipe blancher with pre-washer.
(*Courtesy Berlin Chapman Co.*)

Quality Grading.   At some stage in the preparation of most fruits and vegetables it is usual to carry out some form of grading to ensure that packs of uniform quality are produced, and it is of paramount importance that the quality grading of the raw material in the factory should also be checked by frequent examination and grading of the finished pack.

There are at present no statutory standards for canned foods, other than certain regulations respecting drained weights, can contents, and syrup strength, etc., in force in the United Kingdom as there are in the U.S.A. There is, however, nothing to prevent the canner from adopting his own standards as there is little doubt that as a long term policy quality grading has much to recommend it.

The object of quality grading before processing is to produce a pack, the contents of which will be uniform in size, appearance, flavour and freedom from defects. Quality grading, therefore, implies far more than a mere sorting of products for uniformity of size.

In most cases quality grading involves visual inspection, but for peas several devices have been produced for automatic and continuous sorting into the various grades and as these processes are illustrative of the general principles of quality grading they will be described in some detail.

The green pea for canning has to be picked at a certain stage of ripeness or maturity if the highest quality pack is to be obtained. If it were possible to pick all peas in a given area when they reached an appropriate degree of ripeness the problem would be extremely simple, unfortunately when a field of peas is harvested the condition of the individual peas will vary considerably. The changes occurring during the ripening of peas have been studied by Boswell[59] and more recently by Sidappa and Adam[60] who found that the chief factors responsible for the loss of quality in peas for canning are the gradual loss of sugar, and the increase in starch content which takes place as ripening proceeds. The young peas are of a bright green colour, sweet and tender, but as ripening proceeds the peas become less attractive in appearance, more starchy and tougher. Peas which reach this state before canning tend to produce a cloudy liquor and lack the full pea flavour.

There are at present two main methods of grading peas for maturity, the first is based on the increase in specific gravity which accompanies increase in maturity, while the second is based on the increase in toughness.

In the first method the peas are passed through a brine solution the density of which has been carefully adjusted so that the lighter or less mature peas float, while the denser or more mature peas sink. This is the basic principle, and a very full description of the early work on the subject has been given by Burton[61] who mentions that as long ago as 1919, Funderberg was using this process for the commercial grading of peas. Since those days the method has been considerably extended and various refinements added.

It was soon found, for example, that discrepancies occurred in grading due to the fact that peas contained variable amounts of gas

which caused a variation in density, Burton[61] cites Ames as being the first to discover this phenomenon in which tough peas would float in brine when they ought to sink. This difficulty was overcome by blanching before grading, thereby removing the occluded gas.

The range of brine densities to be adopted depends to a large extent on the markets in which the peas will eventually be sold, Burton[61] quotes the following ranges :—

Fancy peas	..	..	..	1.050 to 1.065 sp.gr.
Choice peas	..	..	..	1.065 to 1.086 sp.gr.
Standard peas		..	..	1.086 to 1.092 sp.gr.

The above grades apply to conditions in the U.S.A., different ranges may well be more suitable for other countries, and the above figures have only been quoted as examples.

One type of flotation quality grader is illustrated in Fig. 58. This particular unit will deliver two grades of peas at high speeds.
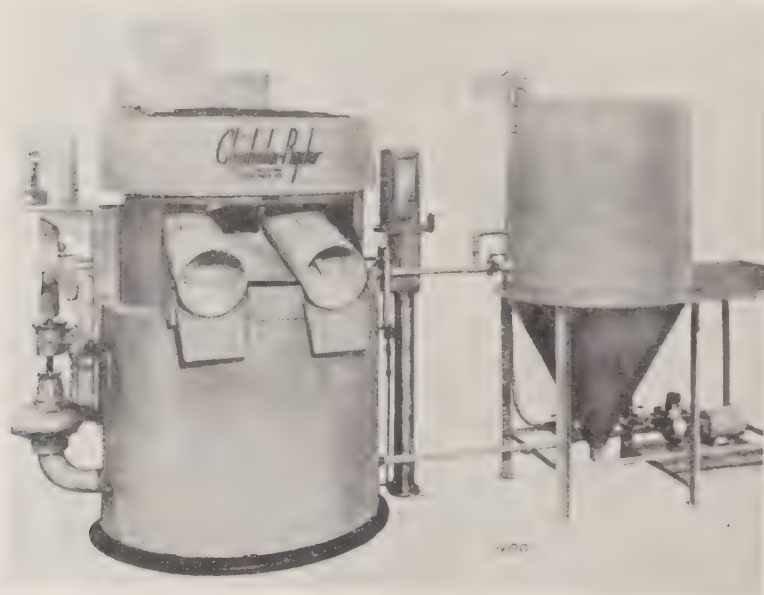
Fig. 58. Flotation quality grader as used for peas with Gravometer to control density of brine (centre), and brine mixer (right).
(*Courtesy Chisholm-Ryder Co., U.S.A.*)

It will be appreciated from the figures quoted above that the control of the brine strength is of considerable importance, and various automatic devices have been developed to deal with this problem. The maintenance of brine strength is complicated by the fact that the brine in the grader is diluted by water carried in by the peas entering

the machine, and also by the fact that brine is carried away by the out-going peas and must be replaced in order to maintain the correct level.

In the second type of grader advantage is taken of the fact that the more mature peas become, the greater is the pressure required to crush them. Martin, Lueck and Sallee[62] have described the operation of a device known as the "tenderometer" which is based on this principle.

This instrument measures the force required to press a given quantity of peas through a standard type of grid. Unlike brine grading only a relatively small sample of the peas to be examined can be tested, as the test results in the destruction of the peas. The method is, however, valuable in determining the maturity of peas during growth as small samples can be quickly examined as ripening proceeds.

The same principle has been applied to several other products including asparagus which was examined by this method by Jenkins and Lee[63]. The method has also been applied to certain fruits.

It will be seen from the preceding paragraphs that considerable attention has been devoted to the development of methods for the preparation and examination of peas for canning. Other vegetables and fruits demand equal care and attention, but in most cases the nature of the material to be examined or graded does not permit the high degree of mechanisation which is characteristic of the modern pea canning line, as illustrated in Fig. 59, and recourse must be had to visual inspection and hand picking.

In addition to the various processes employed in the preparation of vegetables described in the preceding paragraphs, most will necessitate some form of slicing or dicing, and these operations are usually carried out by automatic machines which are fully described in the catalogues of the principal equipment manufacturers and will not, therefore, be described.

Meat. The processes used in the preparation of meat for canning will vary with the type of product being produced. The preliminary stages, however, are usually very similar and consist largely of butchering operations in which the meat is removed from the bones and cut into suitably sized pieces for the subsequent operations.

In some cases the meat will be partially cooked before canning as, for example, in the manufacture of corned beef, and canned roast beef.

An important operation in the preparation of many meat packs is chopping and mincing, and in some cases mixing with other ingredients such as cereals and spices. For some packs such as the many varieties of spiced meat which have been packed during the recent
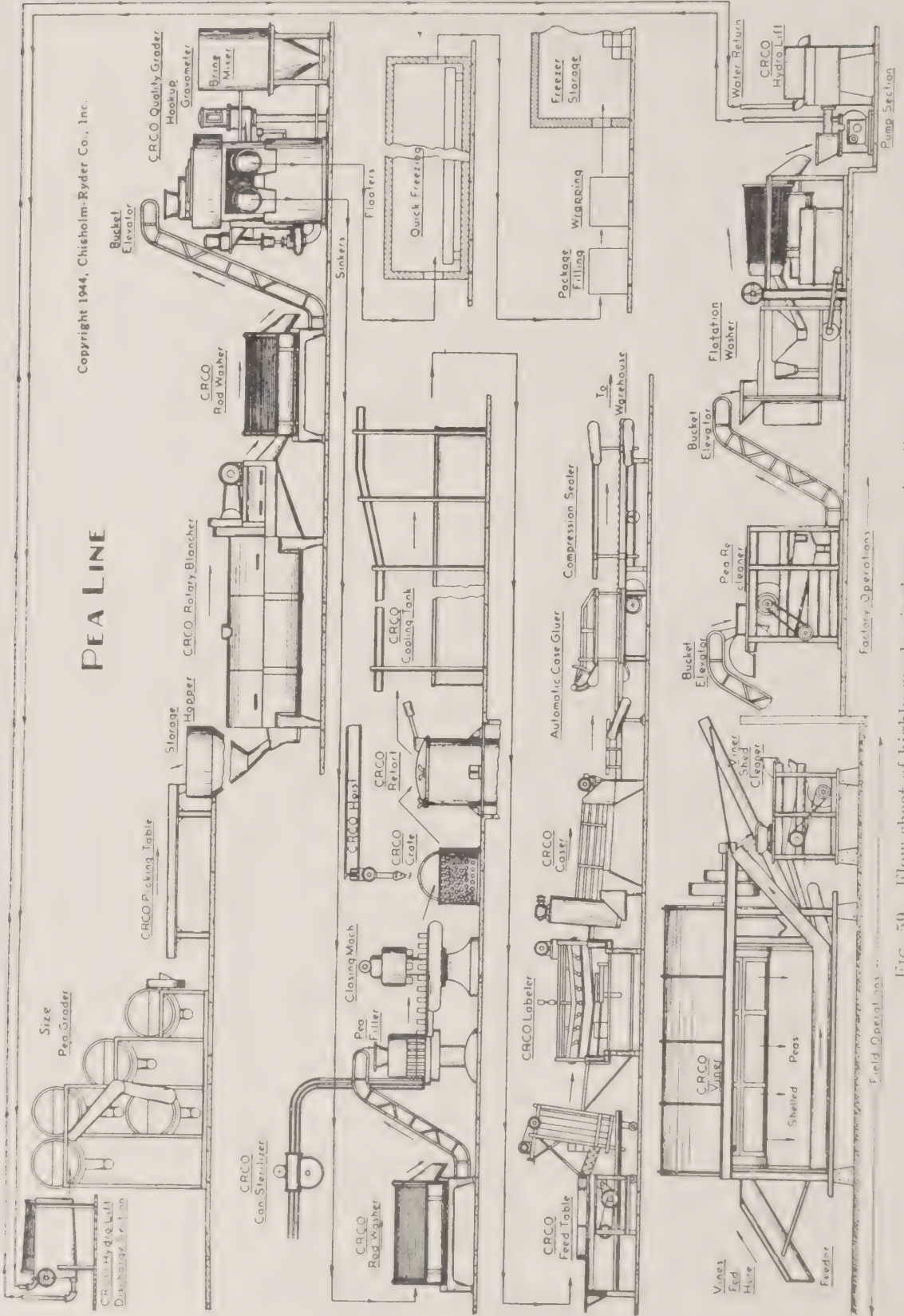
FIG. 59.   Flow sheet of highly mechanised pea canning line.

war a close and uniform texture is desired, this is best obtained if the mixing of the meat and cereal binder is carried out in a vacuum mixer as the occluded air in the meat mixture is thereby eliminated and the desired texture obtained. Furthermore, the development of excessive pressure in the cans during processing is avoided and the exhausting process simplified.

In many packs meat is cured with mixtures of sodium nitrate and nitrite and close attention must be paid to the formulation of the cures and their effect on the processing conditions. The use of cures of this type in the production of spiced and cured ham has been reviewed by Jansen[64].

In handling meat, particular attention must, at all times, be paid to cleanliness and the maintenance of hygienic conditions in the cannery, and it is an advantage if the preparation room can be maintained at as low a temperature as possible. It is also of paramount importance that every care should be taken to avoid holding quantities of warm meat mixtures for an undue length of time before filling and processing, otherwise there is considerable risk of the development of off-flavours and subsequent spoilage.

Fish. The handling of fish before canning calls for the same care that is devoted to meat handling. The fresher the fish can be got into the can the better. The methods used in the preparation of fish for canning depend on the type of product to be packed. In most cases the first stage consists of the removal of viscera and washing the fish. In large canneries this operation is usually carried out automatically while in small canneries the process is often carried out by hand, workers becoming extremely dexterous at removing the head, and most of the viscera, in two almost simultaneous movements.

An important stage in the preparation of many types of fish is brining. This process fulfils two purposes, it flavours the fish, and also improves the texture. The brine used is usually a saturated solution and the time of immersion varies considerably with the size and species of fish. Fish which have been previously skinned can be brined in a shorter time than fish with the skin intact.

Another process which is sometimes used by canners in the preparation of fish is that of curing by smoking. Until recent years the smoking of fish was carried out by rule-of-thumb methods handed down from generation to generation with but little change. Recently, however, efforts have been made to place the process on a sound scientific basis and in this connection mention must be made of the work of the Torry Research Station, Aberdeen, where investigations have been carried out with the object of bringing the traditional processes of smoke curing under scientific control. A paper by Cutting[65] discusses the practical aspect of fish smoking

while an earlier paper[66] by the same author deals with some engineering problems of the process and includes a description of a smoke kiln designed to secure uniform conditions of curing throughout the entire contents of the kiln.

In some packs the product is improved if the fish is pre-cooked before canning, either by steaming, or by frying in oil. This process eliminates excess fluid from the fish and improves the texture. It is extensively employed in the canning of sardines.

A comprehensive account of the preparation and processing of many varieties of fish has been given by Jarvis[39], and the reader is referred to this work for more detailed information on the preparation of the various types of fish used for canning.

In the preceding paragraphs the equipment used in the preparation of a number of canned foods has been briefly described. For details of the many other items of equipment which have not been described the reader is referred to the catalogues issued by the principal suppliers of canning plant and machinery.

Sanitation. Throughout the present volume considerable emphasis is placed on the importance of maintaining hygienic conditions in all parts of the cannery, and it is of especial importance in the preparation room, and at all stages in the preparation of all types of raw materials.

Sanitation in the cannery starts with the purchase of canning equipment and all new equipment should be inspected from the sanitary, as well as the mechanical angle, before purchase. Equipment which is easily cleaned will be kept clean, but equipment with pockets and corners which are difficult to get at will tend to be neglected and remain dirty. In purchasing plant it is particularly important to avoid the following :—

(1) Wooden equipment, as each pore and crack in the wood may harbour spores of thermophilic and other organisms.
(2) Metal equipment not resistant to corrosion ; metal surfaces which become pitted and rough may be almost as bad as wood in providing a harbourage for micro-organisms.
(3) Equipment which cannot easily be taken apart for cleaning. All pipe lines, for example, should be readily dismountable so that they can be cleaned at least once a day. Sharp angles should also be avoided as they are more difficult to clean than rounded corners.

As pointed out by Bashford[66], one of the fundamentals of sound canning practice is that the food should be as free as possible from micro-organisms when the can is closed ready for retorting, and the
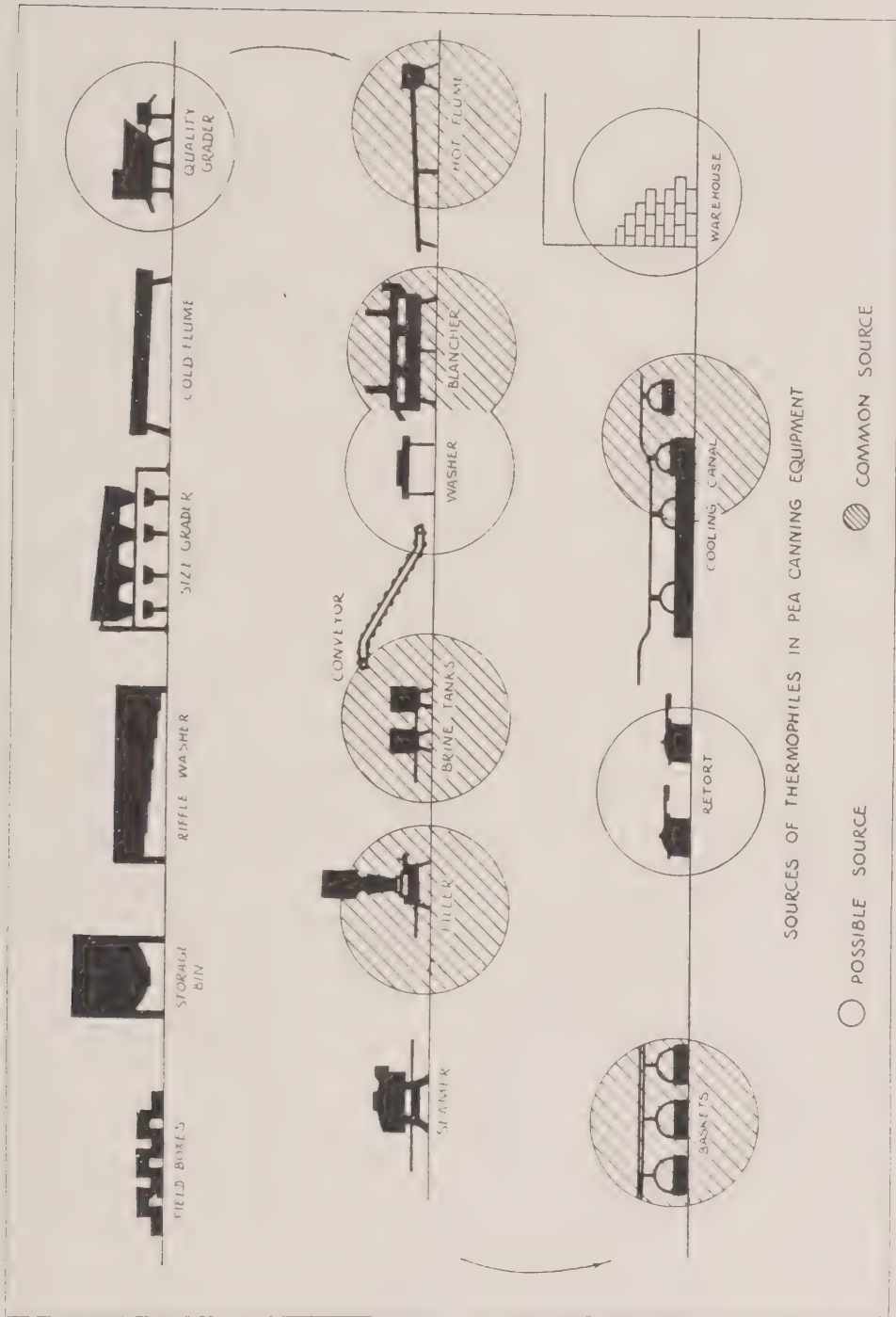
Fig. 60. Schematic diagram indicating sources of thermophilic contamination and multiplication in a pea canning line. (*Courtesy "Food Industries."*)

institution of a regular scheme of plant hygiene will do much to achieve this objective.

Thermophilic organisms have always been a problem to the canning industry as their spores possess a high heat resistance, and they also tend to build-up where suitable conditions occur. The chief sources of thermophilic build-up in vegetable canneries have been reviewed by Lipske and Hubbard[67] and Fig. 60 taken from this review shows in diagrammatic form the chief sources of thermophilic contamination in a pea canning line.

The above authors consider that blanchers are the principal source of infection and that fillers represent the next most dangerous source.

The removal of thermophilic organisms once they have become established in the plant is difficult, and efforts are usually concentrated on preventing their entry and subsequent build-up. The prevention of the build-up of thermophilic organisms is best accomplished by always keeping equipment at temperatures either above or below the range at which multiplication of the organisms takes place, and also by frequent cleaning to prevent the accumulation of dirt and debris at "dead" spaces.

Hygiene should not end with equipment but should also include the personal hygiene of the workers. The provision of proper sanitary facilities, adequate headwear, and clean uniforms will do much to encourage the workers to take an interest in the appearance of the plant and develop a feeling of respect for plant cleanliness.

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HEAT STERILISATION

The fundamental principle upon which the preservation of food by canning is based is the destruction of the spoilage organisms in the sealed container by means of heat.

The practice of subjecting a can of food to a high temperature for a definite time is known as "processing," and the time at which the can is held at an elevated temperature the "process." In the ideal case the process would be of sufficient duration to destroy all the spoilage organisms likely to be present in the can. This would, however, in the majority of cases, result in an unpalatable and poor quality product as most foods are sensitive to heat and suffer in texture and flavour if the heat treatment is unduly prolonged.

The problem the canner has to solve, therefore, is to obtain a *commercially* sterile pack, in other words, a pack which will not deteriorate under normal commercial conditions, although, it may still contain some viable organisms.

It is only during the last twenty five years that the problem of determining a suitable process for a given pack has been approached scientifically and removed from the realm of empiricism in which it originated; previously, the rule-of-thumb methods which were adopted often led to considerable losses through spoilage, due to insufficient processing, or to deterioration in quality due to over-processing.

In formulating a process for a particular product a number of unknown variables which have been summarised by Hallman and Stevens[1] must be decided as follows :—

(1) The determination of the thermal death time of heat resistant spores of spoilage organisms with which the food may be contaminated under normal working conditions.

(2) The determination of the rate of heat penetration of the canned food under investigation.

(3) The calculation of the theoretical process by co-ordination of the thermal death time and heat penetration data.

(4) The checking of the theoretical process, so derived, by inoculating cans of food with the same organism as used for the thermal death time measurements, processing at the calculated time and temperature and then incubating the processed cans to determine if the spores in the inoculum have been destroyed.

In order to appreciate the problems involved in obtaining the data necessary to calculate the theoretical process it is essential that the several factors influencing the heat resistance of micro-organisms, and the rate of heat penetration through a filled can should be properly understood.

Heat Resistance of Micro-Organisms

It is well known that the heat resistance of micro-organisms varies with the particular point of the growth cycle which the organisms have reached. Vegetative cells are destroyed relatively easily by heating in steam at 100°C. for a short time, and do not, therefore, present any great problem to the canner. The ability of certain organisms to form spores, however, which are often extremely resistant to heat, creates the necessity for prolonged exposure to high temperatures before the destruction of these spores can be accomplished.

There are a number of factors influencing the heat resistance of spores, but those of chief interest to the canner in the determination of the processing time and temperature are :—

(1) Time-temperature relationship of the organisms to be destroyed.

(2) The hydrogen ion concentration of the medium in which the spores are located.

(3) The concentration of the spores.

(4) The influence of certain substances such as salt, sugar, sodium or potassium nitrate, oil, etc., which may be present in the food.

(5) Age and environment of the spores.

Time-temperature Relationship. The time required to destroy a given concentration of spores at a definite pH value decreases as the temperature rises, but the death rate is not a linear function, there being considerable variation in the resistance of individual spores. The majority have a relatively low resistance, but a small proportion in each suspension have a high resistance and the thermal death time curve obeys a logarithmic law ; a fact first noticed by Bigelow[2], who used the results of Bigelow and Esty[3] to show that thermal death time curves when plotted on semi-logarithmic paper were represented by straight lines.

The resistance of spores of the same type in identical suspensions is sometimes subject to variation and Esty and Meyer[4] found strains of the same organism in which the heat resistance ranged from 3 to 100 minutes at 105°C. The same authors also demonstrated that the maximum resistance of spores of *Clostridium botulinum* when heated in a buffered phosphate solution of pH 7.0 was as follows :—

4 minutes at 120°C. (248°F.)   100 minutes at 105°C. (221°F.)

10 minutes at 115°C. (239°F.)   330 minutes at 100°C. (212°F.)

32 minutes at 110°C. (230°F.)

These results have been widely used as a standard for the calculation of processes for many types of canned food.

The Influence of the Hydrogen Ion Concentration. Of the several factors which affect the heat resistance of micro-organisms the hydrogen ion concentration of the medium in which the spores are heated is one of the most important. The work of Bigelow and Esty[3], Esty and Meyer[4], and of Cruess, Fong and Liu[5] has shown that the maximum heat resistance of bacterial spores occurs when the

FOOD	pH	EXPOSURE IN MINUTES
EGG PLUMS	2.10	
GOOSEBERRIES	3.00	
RASPBERRIES	3.16	
STRAWBERRIES	3.22	
APPLES	3.24	
SAUERKRAUT	3.26	
CHERRIES	3.30	
CIDER	3.30	
BLUEBERRIES	3.40	
BLACKBERRIES	3.55	
APRICOTS	3.62	
PEACHES	3.70	
BARTLETT PEARS	3.85	
TURNIPS	4.10	
PUMPKIN	4.22	
TOMATOES	4.40	
CARROTS	5.05	
BEETS	5.13	
ASPARAGUS	5.16	
WAX BEANS	5.22	
SWEET WRINKLED PEAS	5.30	
SQUASH	5.30	
SWEET POTATOES	5.36	
STRING BEANS	5.40	
PORK & BEANS – TOM. SAUC.	5.40	
SPINACH	5.40	
BRUSSELS SPROUTS	5.46	
PORK & BEANS – PLAIN SAUCE	5.69	
RED KIDNEY BEANS	5.70	
LIMA BEANS	5.77	
CHILE CON CARNE	5.82	
SUCCOTASH	6.00	
SWEET CORN	6.21	
CLAM CHOWDER	6.26	
SHRIMP.	7.00	
HOMINY	7.40	

(Chart annotation: "Time Required to Destroy the Spores of *Cl. botulinum* at 100°C.")

FIG. 61. Chart showing pH value of various foods and the effect of variation of pH value on the thermal resistance of spores of *Cl. botulinum.*

(*Weiss.*)

pH value of the surrounding medium is between pH 6 and pH 7, and that it decreases rapidly on either side of the neutral point. Williams[6], working with spores of *Bacillus subtilis*, found the same effect, as also did Weiss[7] in the case of *Clostridium botulinum*, the spores of which in acid foods only survived for about 10 minutes, whereas in foods with a pH value approaching the neutral point the survival time was as much as 170 minutes at the same temperature. The chart by Weiss[8], Fig. 61, shows the average pH value of various foods and it will be seen that, although a large proportion fall in the lower pH ranges, a considerable number are in the pH 5 to 6 range where the heat resistance is on the up-grade as shown by the survival times of spores of *Clostridium botulinum*.

Concentration of Spores. In a given suspension the thermal death time increases with any increase in the number of spores to be destroyed, a phenomenon which would, of course, be expected from the logarithmic course of death.

The effect of the increase in concentration on the thermal death time, was first noted by Schmidt[9] and also by Gage and Stoughton[10], and it is a factor of considerable importance in the sterilisation of canned foods. Table IX from the results of Esty and Meyer[4] shows

TABLE IX

The Relationship between Concentration of Spores of *Clostridium botulinum* **and Heat Resistance**

(Esty and Meyer)

Strain	Number of spores per 1 cc.	Resistance in mins. at 105°C.		Resistance in min. at 100°C.	
		+	−	+	−
90	900,000,000	41	48		
	9,000,000	34	36		
	90,000	18	20		
	900	12	14		
	9	—	2		
90	628,000,000	33	36		
	6,280,000	33	36		
	62,800	24	27		
	6,280	15	18		
	628	10	15		
	63	—	5		
97	72,000,000,000			230	240
	1,640,000,000			120	125
	32,800,000			105	110
	650,000			80	85
	16,400			45	50
	328			35	40

that any variation in the concentration of the spores will have a profound effect on the efficacy of the sterilising process.

The variation in heat resistance of individual spores is one reason for the difficulty in obtaining consistent results from successive thermal death time determinations, and Baumgartner[11] refers to the terms "majority" thermal death time as applied to the destruction of 99.9 per cent of the spores and the "absolute" thermal death time as that required for the destruction of every cell.

Effect of Salt. The presence of salt in a pack often has considerable effect on the heat resistance of spores. It frequently happens, according to Viljoen[12], that the sudden failure of a process which has been working satisfactorily for some time is due to some variation in the salt concentration of the pack. Working with pea liquor he found the highest degree of protection occurred with a concentration of 1 to 2.5 per cent salt. Further work showed that the heat resistance increased up to about 2.5 per cent salt content and then decreased in the manner shown in Table X. Esty and Meyer[4] using spores of *Clostridium botulinum* also confirmed that heat resistance was enhanced at 1 to 2 per cent salt concentration and then became less with increasing concentrations being considerably reduced with 8 per cent, 15 per cent and 20 per cent salt.

TABLE X

The Effect of Various Concentrations of Sodium Chloride on the Heat Resistance of Spores

(*Viljoen*)

Salt concentration	Positive tubes
%	%
0	15
0.5	37.8
1	86.7
1.5	73.3
2	75.6
2.5	78.9
3	40.0
4	13.3

In each case 300,000 spores per cc., temperature 115°C., and 25 tubes in each set.

Effect of Sugar and Syrup. The presence of sugar or syrup renders the destruction of micro-organisms more difficult. Weiss[7] observed this effect with spores of *Clostridium botulinum*, while Baumgartner and Wallace[13] observed the same effect in the case of non-sporulating organisms such as *Escherichia coli*.

Delayed Germination. It has frequently been observed that spores will not germinate even under apparently ideal conditions of growth. Dickson *et al.*[14], and Burke, Sprague and Barnes[15], for example, observed that spores of *Clostridium botulinum* and of common aerobic bacteria could lie dormant for months, or even years, in spite of the existence of favourable growth conditions. Williams[6] has carried out an extensive review of the literature on the subject, but of the various theories which have been put forward in an attempt to explain the phenomenon none are entirely satisfactory.

An interesting instance of delayed germination has been quoted by Lang[16] who drew attention to the occurrence of the phenomenon when viable spores are trapped in an oil medium as in the case of canned sardines.

The explanation hitherto advanced to account for delayed germination when spores are heated in an oil medium is based on the marked difference in the thermal conductivity of the oil according to whether it contains moisture or not.

Clayton[17], however, offers an alternative suggestion based on colloid chemical principles and his explanation will extend to the somewhat different problem of non-sterility in vegetable salad (diced vegetables) in mayonnaise.

The basic fact is the observation by Ascherson[18], when he "made the important discovery *that coagulation in form of a membrane occurs inevitably and instantaneously when albumin comes into contact with a liquid fat*, and that consequently an oil drop cannot be surrounded even for a moment by an albuminous liquid without a vesicular membrane or a cell forming round it."

Acutely anticipating modern opinion (based on the classical work of Hardy[19], Langmuir[20], and Harkins[21]), Ascherson[18] wrote of the membrane formation "as a physical property, as a kind of capillary condensation which proceeds at the boundary of heterogeneous liquids in contact."

Long dormant, Ascherson's profound experiment has been repeatedly confirmed. We now realise that not only proteins, but many other hydrophilic colloids like saponin, gums, Irish moss, bile salts and soaps form distinct interfacial membranes when their aqueous solutions make contact with an oil. It is important to note that *the speed of formation, as well as the strength of, the membranes depend on the make-up of the contacting phases.*

Investigations by Serrallach and Jones[22] showed that when a given aqueous colloid was used against a series of oils, or a given oil was used against a series of acqueous colloids, the *rate* of membrane formation showed striking variations, whilst the *general physical properties* of the membranes differed considerably. For instance, the

system : aqueous gelatin/oil formed a film quickly with cod liver oil, but very slowly (taking up to 15 days) with mineral oil. Whereas the film against cod liver oil was opaque, brittle, wrinkled, and easily folded, that against mineral oil was translucent, thin, elastic, and weak.

The cause of interfacial "condensation" is the orientation of the molecules of both phases at the boundary. The quite different molecular structures of cod liver oil and mineral oil at once account for the above results. Cod liver oil, having polar groups in its molecule, will orientate more rapidly than the non-polar mineral oil.

The application of the Ascherson observation to the behaviour of bacteria in an oil environment readily follows. Bacteria (excluding the not relevant fatty-capsulated strains) are hydrophilic colloids in make-up. Positioned in an oil phase, the bacteria will inevitably receive a membranous interfacial envelope. The nature of the oil will determine the rapidity of attainment of the envelope and its physical properties. Time will be a dominating factor throughout.

Now comes the important question : what happens when dormant oil-cased bacteria become re-distributed in the aqueous phase ? This question underlies the problem of incubating the food after violent shaking so as to re-distribute the bacteria between the aqueous and oil phases. Two answers are theoretically predictable.

First, it is conceivable that a bacterium cased with a membrane will now have that membrane exhibiting a lipophilic exterior which, in the presence of aqueous phase hydrophilic colloid, will cause a second orientation membrane. An "onion-skin" build-up is theoretically feasible.

Secondly, it is conceivable that a bacterium cased with a membrane will have that membrane peptized by the strong orientation forces at the new interface.

Experimental work of considerable difficulty in both physical chemistry and bacteriology is needed to establish the rationale of the subject.

A further aspect concerns the viability of bacteria in salad dressing and mayonnaise, where the oil phase is now finely subdivided in the aqueous external phase. It is likely that Nugent's[23] modification of the Mudd[24] interface technique would be a valuable tool in the study of the passage of bacteria from the aqueous phase into the oil phase and vice versa.

Influence of Environment and Age of Spores. Any change in the medium in which the spores are growing may affect their heat resistance. Williams[6] working with spores of *Bacillus subtilis* found that by changing the nutritive and environmental conditions the heat resistance of the spores was changed.

Esty and Meyer[4] have found that young moist spores of the first generation have the highest heat resistance and that a gradual decrease in heat resistance occurs as the spores age. Weiss[7] found

that spores one month old had a heat resistance three times greater than those five months old.

This variation in resistance of spores has led Baumgartner[11] to point out that the heat resistance of laboratory produced spores should not be too readily interpreted as representing conditions existing in factory practice as it is a common experience to find that spores normally of a highly heat resistant strain often have a much lower heat resistance after storage under laboratory conditions.

The Choice of a Test Organism

The process finally adopted for any can of food must be sufficient to destroy the most heat resistant organism likely to be encountered, and at the same time avoid any undue deterioration in the quality or flavour of the contents of the can. The choice of a test organism to be used in thermal death time determinations is, therefore, of considerable importance. It has been the common practice to adopt the times and temperatures found necessary by Esty and Meyer[4] to destroy the spores of *Clostridium botulinum* produced under the optimum conditions of temperature, environment etc., and heated in a buffered phosphate medium of pH 7.0. A typical thermal death time is shown in Fig. 62.

Further work on the heat resistance of
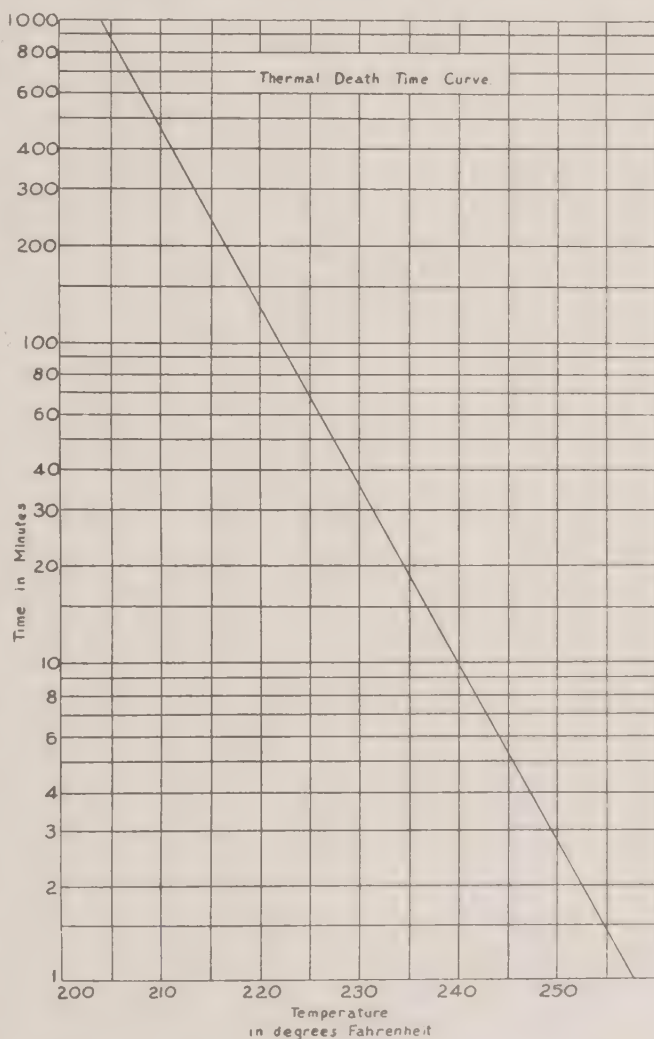
Fig. 62. Typical thermal death time curve.
(*Courtesy American Can Co.*)

micro-organisms, however, has resulted in the discovery of a number of organisms with a greater heat resistance than that of *Clostridium botulinum*. Meyer and Lang[25] have isolated an anaerobe which they called *Clostridium caloritolerans* whose spores survive for 520 minutes at 100°C. in pH 7.0 buffer solution. Similarly, Baumgartner and Wallace[26] have found a strain of *Clostridium sporogenes* which survived heating for 15 hours at 100°C. Cameron[27] isolated an anaerobe of high heat resistance which he designated No. 3679, and Townsend, Esty and Baselt[28] working with this organism, and with spores of *Clostridium botulinum*, found that the heat resistant properties differed in food media but were essentially the same in buffered phosphate.

Williams[29] has reviewed the whole question of the choice of organism to be used for the thermal death time measurements and mentions the use of three organisms of greater heat resistance than *Clostridium botulinum*. These organisms *Clostridium sporogenes*, strain No. 3679, *Clostridium thermosaccharolyticum*, strain No. 3814, and *Bacillus stearothermophilus*, strain No. 1518, have a resistance of 15 to 16 mins., 60 to 70 mins., and 130 to 140 mins. respectively when heated in phosphate buffer solution at 115°C. as compared with a resistance of 10 mins. for *Clostridium botulinum* under the same conditions.

The heat resistance is not the only factor which must be considered when selecting a test organism for thermal death time determinations ; the type of spoilage which is likely to occur, and the conditions under which the canned food is to be used and stored are of importance. If, for example, the cans are to be exported to hot climates, thermophilic spoilage is possible and the processing must be adjusted accordingly by the use of a suitable test organism.

Determination of the Thermal Death Time

Thermal death time measurements were first put on a sound basis by Bigelow and Esty[3] who defined the thermal death time as the time required to destroy a known number of spores at each of several temperatures. A number of standard sized tubes were used and inoculated with a definite quantity of spore suspension from which the vegetative forms had previously been removed by pre-heating. The tubes after inoculation were sealed in an oxygen flame and then immersed in an electrically-heated oil bath adjusted to maintain a constant temperature throughout the experiment. At definite periods of time a single tube was removed, cooled in ice water, and then held in a refrigerator until determinations of sterility could be made. The time intervals were so arranged as to determine the heat resistance within close limits. In this method a common occurrence is the presence of "skips" i.e. certain tubes do not show growth after a period of heating which would not normally result in the destruction

of their contents. These skips may be accounted for by variation in the heat resistance of individual spores.

A modification of the above method, designed to eliminate the incidence of skips, was proposed by Esty and Williams[30] who used a large number of tubes, at least 25 to 30, all containing the same suspension, and all heated alike for at least four different times so as to cover the desired range of heat resistance. The results so obtained are then plotted on semi-log paper and the thermal death point may be read off for any given time and temperature.

Williams, Merrill and Cameron[31] pointed out that, although, the absolute thermal death was determined by the above methods, no data was obtained on the course of spore destruction and they, therefore, constructed a thermal death time "tank" which permitted the heating of a mass suspension under pressure and the aseptic withdrawal of samples at selected intervals without disturbing the test conditions and with no limitation on the number of samples which could be withdrawn other than the capacity of the tank.

A further development was the introduction of the thermal death time can by Townsend, Esty and Baselt[28]. In this method a can of dimensions 208 x 006 was used, and a suitable medium or some of the food to be sterilised was introduced into the can which was then inoculated with a known concentration of spores of the test organism and closed under a vacuum of 15 to 22 inches. The sealed can was heated for the requisite time and then incubated without sub-culturing. Growth was usually determined by bulging of the can end.

The heating was ingeniously carried out in a battery of small retorts all operating from the same steam line, the steam being drawn from a large retort automatically maintained at the desired temperature. The apparatus is shown in Figs. 63 and 64.
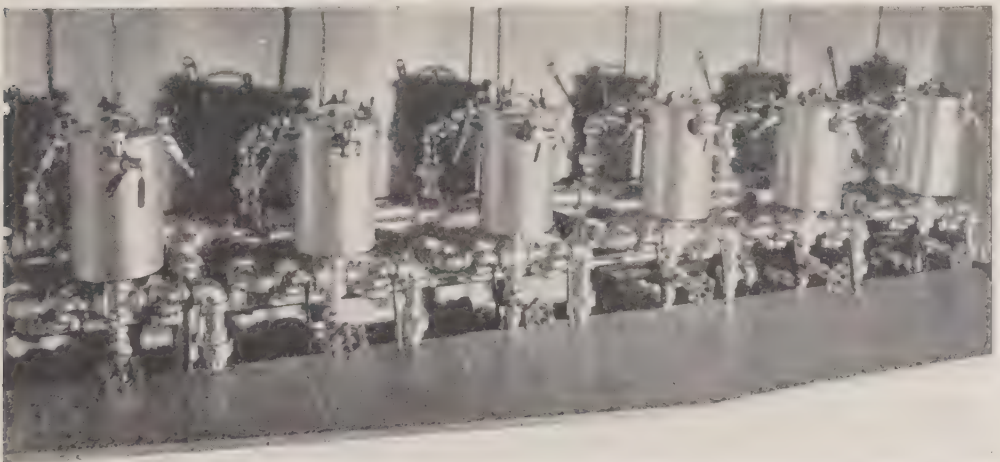
Fig. 63. Battery of small retorts used for the determination of thermal death times. *(Courtesy American Can Co.)*

Fig. 64.   The sealed thermal death time cans being placed in one of the retorts.
(*Courtesy American Can Co.*)

Corrections were applied for the lag in heating and cooling, but it was found that, in general, this correction was less for the thermal death time can than for glass tubes owing to the superior conductivity of the metal can.

Of the methods described above that due to Esty and Williams[30] is the most used as it is capable of giving satisfactory results without the use of elaborate apparatus.

Heat Penetration

Before a process can be fixed for any canned food the rate of heat penetration to the slowest heating portion of the can must be deter-

mined. In the normal type of cylindrical can the point of slowest heating lies at a point on the vertical axis midway between the two ends, and the temperature at this point is taken as the basis of all heat penetration studies.

The first attempt to study the time-temperature relationship in a can during processing was made by Prescott and Underwood[32] by inserting maximum thermometers in the centre of cans and thus recording the highest temperatures reached during the heating period. A similar method was adopted by Kochs and Weinhausen[33] who carried out experiments with cans, glass jars and earthenware containers.

A thermocouple was used by Bovie and Bronfenbrenner[34] to obtain a continuous record of the temperature in a can during heating, and a similar method was used by Bitting and Bitting[35] who obtained complete records of the heating cycle during processing.

Further work by Thompson[36] using a thermocouple to measure the temperature at the centre of filled cans resulted in the development of a mathematical relationship for time and temperature during the heating of filled cans. A later paper[37] by the same author discussed the theory of heat penetration taking into account the sterilising effect of the cooling period.

The transfer of heat from the heating medium to the centre of the can may take place in two ways :—

    (1) By conduction.
    (2) By convection.

In conduction heating the transfer of heat takes place between adjacent molecules and there is, therefore, no actual transfer of material. The passage of heat from the heating medium to the centre of the filled can is, therefore, a relatively slow process.

Convection heating, on the other hand, takes place by the development of movements and currents in the material being heated and a circulating system is set up resulting in a relatively rapid establishment of a state of equilibrium between the exterior and the centre of the can. It will be seen, therefore, that the rate of heat penetration depends on the consistency of the contents of the can and will take place relatively slowly with the more solid foods where heat transfer takes place chiefly by conduction heating and more or less rapidly in liquid or semi solid foods where convection heating can take place.

Each mode of heating has its own characteristic heating curve, the different types being well illustrated by the results of Jackson and Olsen[38] who used varying concentrations of bentonite suspensions to

simulate different types of canned foods. The curves shown in Fig. 65 illustrates convection and conduction heating, also a broken type of heating curve where heat transfer takes place by both methods. Generally speaking liquid packs such as fruit juices, beer, evaporated milk, and thin soups heat by convection, while the more solid packs such as galantines, solid meats and very thick soups by conduction. Other packs such as fairly thick soups, tomato puree, etc., show the broken type of heating curve. The factors of major importance which influence the rate of heat penetration are :—

(1) The nature of the contents of the can.

(2) The size and shape of the container.

(3) The type of process (agitating or still).
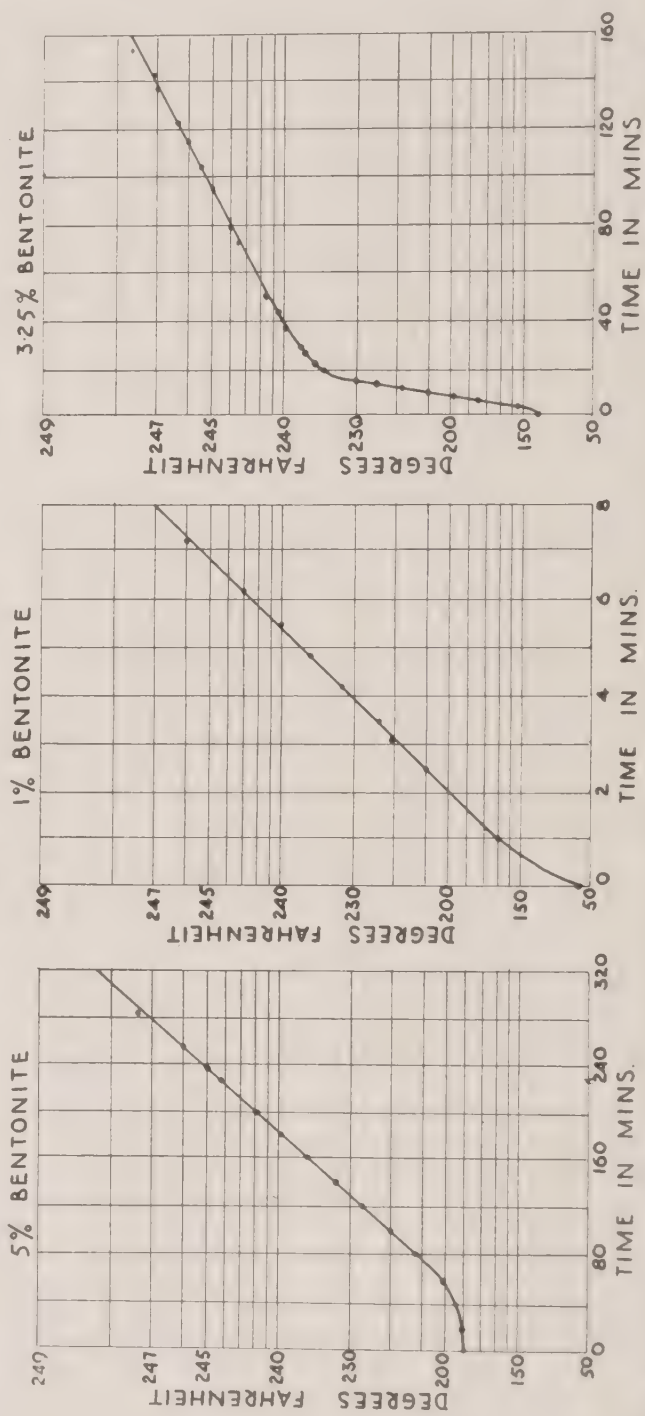
Fig. 65. Heat penetration curves obtained by using bentonite suspensions to simulate various types of canned foods. Heating taking place mainly by conduction (left), convection (centre), and first by convection and then by conduction (right).

(Jackson and Olsen.)

Heat penetration reaches a maximum value when the can is filled with water and there is complete freedom for the development of convection currents ; products packed in water, brine or thin syrup,

therefore, usually have a high rate of heat penetration. If the solid constituents of the pack are small in size, as in the case of peas which heat up rapidly and do not exert a prolonged cooling effect on the pack, heat penetration is rapid and takes place almost as quickly as if the peas were not present. Products which soften on heating, pack together, or consist of large pieces of insoluble material tend to retard heat penetration as the heating of the liquor is delayed until the solid portions of the pack are heated to the centre.

The addition of starch slows down heat penetration as shown in Fig. 66 after Bigelow *et al.*[39] It will be observed that the maximum retardation occurs at approximately 6 per cent starch content and the addition of further quantities appears to make little difference. Small amounts of gelatin, pectin, gums and similar substances have the same action.
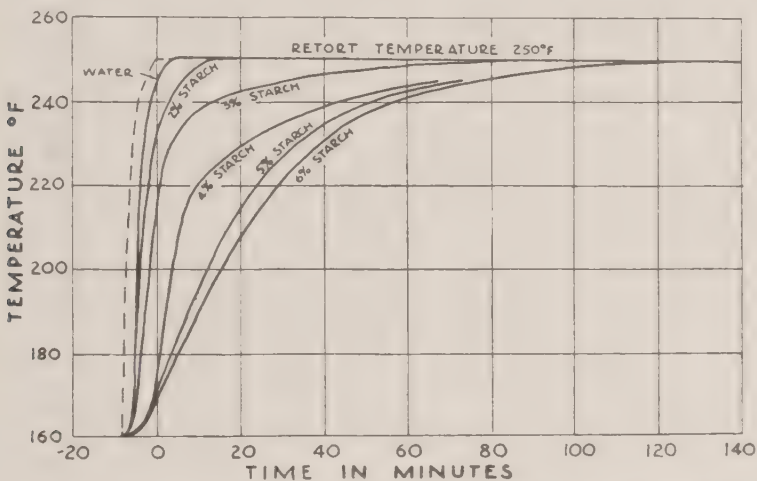
FIG. 66. The effect of the addition of starch on the rate of heat penetration.
(*Bigelow* et al.)

As would be expected, the larger the can size the longer the time required for heat to penetrate to the centre. This is particularly the case where heat transfer takes place largely by conduction. Broadly speaking, for cans where the length is greater than the diameter and heating is largely by conduction, the time required for heat to penetrate to the centres of two cans under the same heating conditions is proportional to the squares of their respective radii.

The effect of agitation during processing depends on the consistency of the can contents, but in packs which do not readily permit the formation of convection currents, but are still fluid enough to allow mixing of the contents, agitation is a valuable means of increasing the rate of heat penetration and reducing the processing time. The results of Adam and Stanworth[40], Table XI, illustrate this point.

TABLE XI

Heat Penetration in A.10 Cans of Beans in Tomato Sauce

(*Adam and Stanworth*)

Processing temperature °F.	Method of rotation	Time taken to reach central temperature of			
		225°F. mins.	230°F. mins.	235°F. mins.	240°F. mins.
240	Stationary	200	235	300	—
250	Stationary	165	190	220	260
240	Rotated 5 revs./10 secs. 20 secs. stop	9	$10\frac{1}{2}$	$12\frac{1}{2}$	—
240	Rotated 4 times/min.	12	$13\frac{1}{2}$	17	—
250	Rotated 4 times/min.	10	$11\frac{1}{2}$	13	16

In an extensive paper on heat penetration in canned foods, Bigelow *et al.*[39] state that, in addition to the above, the following factors are of importance in determining the final process :—

(1) The initial temperature of the filled can immediately before retorting.
(2) Coming-up time of the retort.
(3) The method of cooling.

If two cans of the same size and containing the same product, heated to different temperatures, are placed in a retort and processed together, the can with the lower initial temperature will heat more rapidly and the centres of the two cans will reach the retort temperature at the same time. According to Baumgartner[11] the destruction of spore forming organisms in low-acid and medium-acid foods is usually considered to commence at 93.3°C. and all time spent above this must be taken into account in assessing the total lethal effect of the process. It will be readily seen, therefore, that, although, cans with different temperatures may eventually reach the retort temperature at the same time, the can with the highest initial temperature will be subjected to a process of greater lethal value than a can with a lower initial temperature. It is important, therefore, to avoid any prolonged delay between closing the can and processing as any appreciable cooling will reduce the total lethal effect of the process.

The coming-up time of the retort and the duration of the cooling process influence the total lethal effect, and must be taken into consideration, particularly where short overall processing times are being used as in the case of acid fruits and vegetables.

The modern method of determining the rate of heat penetration is to mount a thermo-couple at the centre of the can, as shown in Fig. 67, fill the can with the food under investigation, seal and transfer to the retort. A series of readings of time and temperature are then taken while the retort is held at the processing temperature and a time-temperature curve is plotted from the results so obtained. A typical curve obtained by this method is shown in Fig. 68.

The necessity of heating non-acid products for considerable periods in order to ensure the sterility of the pack has focused attention on the possibility of using very high processing temperatures with a corresponding reduction in the time of the process. The use of high temperatures and short times has resulted in the name "high-short" being given to this procedure. Short times necessarily imply a high rate of heat penetration and the use of high-short processes has so far been confined to the type of pack where convection heating takes place. The possibility of carrying out some or all of the heating before the can is filled has, however, been visualised,

FIG. 67. Method of mounting thermo-couple in centre of can to determine rate of heat penetration.
(*Courtesy American Can Co.*)

and Ball[41] has reviewed the methods for high-short processing, dividing them into five classes as follows :—

(1) Food heated but not completely sterilised before filling the can.
(2) Food completely sterilised before placing in the can.
(3) Food heated in the can before sealing and sterilisation completed after sealing.
(4) Food heated in the can and completely sterilised before sealing.
(5) Food heated in the can after sealing.

High-short processing has so far been confined to such products as milk, corn, peas, beans, fruit juices and soups.

Many patents have been granted for the rapid sterilisation of food before sealing, but the majority fail when it comes to the final sealing of the can under aseptic conditions.

Use of a special valved can has been described by Ayers[42]; this device permits the flash pasteurisation of fruit juice and the temperature can be raised from 110°F. to 210°F. in about 10 seconds. This process has also been used experimentally in the sterilisation of evaporated milk, peas, string beans, etc., but has never found extensive commercial application owing to the complication of the valved can.
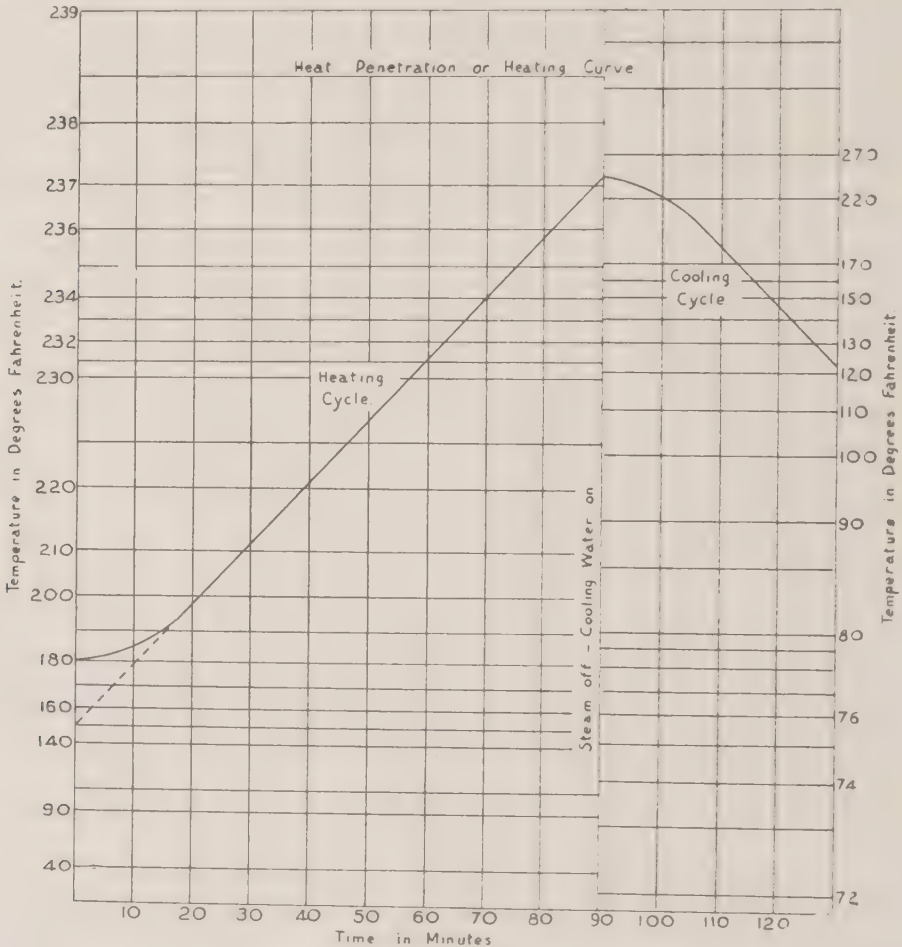
FIG. 68.   Typical heat penetration and cooling curve.
(*Courtesy American Can Co.*)

Foods which are packed in large pieces such as solid meats are, according to Ball[41], unlikely to be sterilised where heat is applied externally and the chief possibility of high-short processing in these cases appears to lie in some form of dielectric heating where heat is generated within the body of the food by means of high frequency currents; further reference to this process is made in Chapter 12. Although the slower heating packs are not easily processed by high-short methods a large tonnage of the total canned food output

consists of liquid or semi-liquid packs to which this method may be applied, and there is no doubt that the improvement of texture and flavour obtained by the high-short method will lead to its increased adoption. Temperatures as high as 400°F. may well be used when equipment has been designed to withstand the high pressures involved.

Calculation of the Process

Commercial processes are usually selected so as to subject the food to the minimum heat treatment consistent with the destruction of the most heat resistant organism likely to be encountered in the can. By this means, the texture and quality of the contents of the can are retained to the maximum possible extent.

The duration of the process and the temperature which has to be used are determined to a great extent by two factors ; the rate of heat penetration, and the acidity of the food to be sterilised. Experience has shown that from the processing point of view canned foods may be divided roughly into three classes :—

(1) Acid foods with a pH value below 4.5.
(2) Semi-acid foods with a pH value between 4.5 and 6.0.
(3) Non-acid foods with a pH value of 6.0 and over.

Spoilage organisms in foods of pH 4.5 and below can usually be destroyed by heating for a short time at 100°C. and do not, therefore, present any great problem, but above pH 4.5 highly heat resistant organisms are found and the use of temperatures in excess of 100°C. is necessary in order that the processing time is not unduly prolonged. It is, therefore, with the semi-acid and more especially the non-acid foods that the accurate calculation of the process becomes of paramount importance.

When the thermal death time of the selected test organism, and the rate of heat penetration for the product to be sterilised have been determined, all the information required for the calculation of the process is available.

The appearance of a paper by Bigelow *et al.*[39] marked the beginning of the application of scientific method to the problem of co-ordinating thermal death time and heat penetration measurements and as their method can be applied to all types of products and can sizes it is usually referred to as the "general" method. The application of the "general" method of thermal process calculation requires that the thermal death times of the selected test organism be known for all temperatures within the processing range and that the heat penetration data refer to the product and size of can to be sterilised.

The thermal death times for all temperatures within the processing range may be found by plotting the values obtained experimentally

as in Fig. 61, using a logarithmic time scale, joining the points by a smooth curve and reading off the required times and temperatures. The next step is the construction of the lethal rate/time curve. The lethal rate refers to the rate of destruction of the selected test organism used for the thermal death time measurements : for any given temperature the lethal rate is the reciprocal of the thermal death time at that temperature. Any temperature on the heat penetration and cooling curve may be given an appropriate lethal rate, and if a curve is constructed in which temperatures are substituted by lethal rates, a lethal rate/time curve, or lethality curve, as it is sometimes called, is obtained. It follows from the definition of the lethal rate that a process sufficient to destroy the spores of the test organism will be that combination of time and temperature which will give an area equal to unity under the lethal rate/time curve. The total lethal effect of any process may be determined, therefore, by measuring the area under the lethal rate/time curve within the appropriate limits of time and lethal rate.

This method of calculating processes, although, very wide in its application is laborious and can only be applied to those packs in which the conditions are the same as those under which the heat penetration curve was obtained. Several efforts have been made to simplify the procedure. The ideal method would, of course, be to have heat penetration curves for each type of pack to be processed, but the great amount of work involved prevents this, and Ball[43] has derived equations based on the work of Thompson[36, 37] by which some of the commoner processing problems may be solved mathematically without recourse to the graphical method outlined above. The method, however, can only be applied to those cases in which the major portion of the heat penetration curve is a straight line when plotted on semi-logarithmic paper, a condition fulfilled by packs heating mainly by conduction. Furthermore, although, the graphical method is avoided, the calculations are somewhat involved. The calculations have been simplified to some extent by the use of nomograms developed by Olson and Stevens[44], while Schultz and Olson[45] have given formulae for the conversion of heat penetration data from one set of retort conditions to another. In the method developed by Ball[43] the thermal death time curve is defined in terms of "z," a value which represents the slope of the thermal death time curve for the organism, and "F" a numerical value arbitrarily chosen as the number of minutes required to destroy the organism at 121.1°C. (250°F.). The "z" value is expressed as the number of degrees Fahrenheit required for the curve to pass through one logarithmic cycle. The values of "F" and "z" for spores of *Clostridium botulinum* under the conditions used by Esty and Meyer[4] have been stated by

Olsen and Stevens[44] to be 2.78 minutes and 18°F. respectively, but it is important to realise that the values for a particular organism will vary with the conditions under which it is heated.

The heat penetration curve may be similarly defined by two factors "j" and "fh."

Taggart and Farrow[46] describe a method by which heat penetration data obtained for one can size and for one process may be employed for the calculation of heat penetration curves for cans of the same size retorted at different temperatures, or for cans of a different size
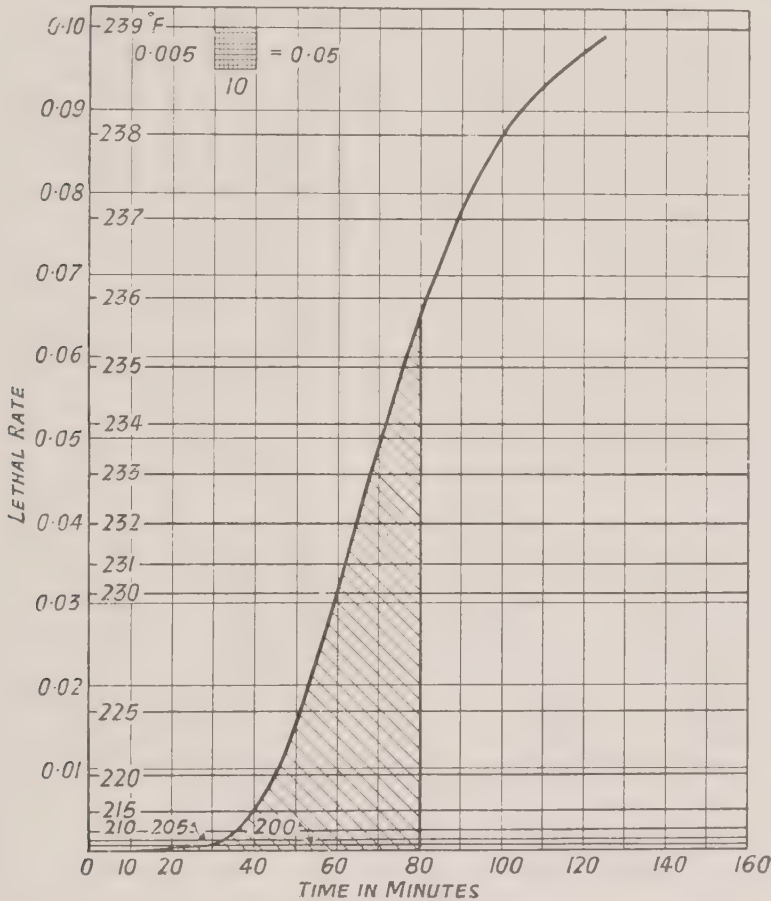
Fig. 69. Lethal rate/time curve plotted on special graph paper.
(*Courtesy "Food."*)

retorted at any selected temperature. This method also is limited to products which heat mainly by conduction. The authors have ignored the lethal effect of the cooling portion of the heat penetration curve and regard any additional sterilising effect as a safety factor.

The same authors have developed a special graph paper[47] to simplify the plotting of the lethal rate/time curve and using this paper

it is only necessary to replot temperature against time as obtained from the heat penetration curve to obtain the corresponding lethal rate/time curve. The special paper is prepared by drawing temperature lines on the vertical scale at distances from the horizontal base line proportional to the lethal rates at the corresponding temperatures, an example of this type of curve is shown in Fig. 69.

Some practical results on heat sterilisation have been given by Lewis[48] who compared the sterilising value of processing a given pack at different temperatures, his results shown graphically in Fig. 70, and in tabular form in Table XII, demonstrate
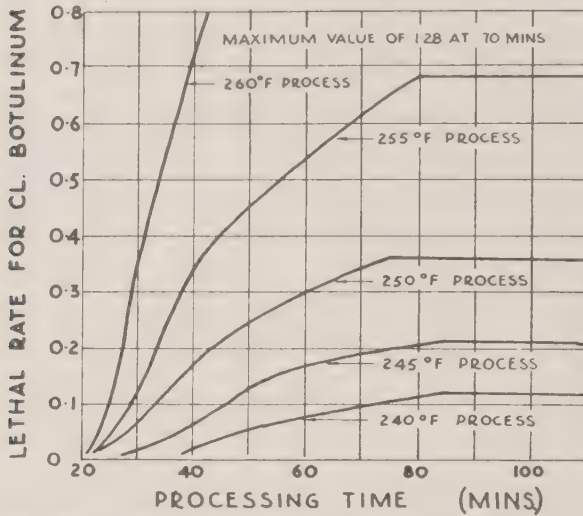
FIG. 70. Lethal/rate time curves for *Cl. botulinum* at different processing temperatures.
(*Courtesy "Food."*)

the great difference in time required to obtain the same lethal effect at different temperatures and thereby emphasise the need for the accurate control of processing conditions, particularly at the higher temperatures.

TABLE XII

Relationship Between Processing Temperature and Time Required to Reach a Given Lethal Value

(*Lewis*)

Processing temperature	Time required to give a lethal value of 11.2 for *Cl. botulinum*
F.	mins.
240	150
245	101
250	76
255	58.5
260	43

Checking the Calculated Process

After calculating the process for a given pack by one or other of the methods outlined in previous paragraphs it is usual to check the accuracy of the calculations by carrying out a practical test under normal working conditions. An experimental batch of the food to be

processed is made up and filled into cans, the filled cans are then inoculated with a suspension of the test organism used in the thermal death time measurements, the concentration being so adjusted as to correspond to that likely to be encountered in practice. In carrying out the inoculation it is important to ensure that the inoculum is well distributed throughout the cans and not merely deposited near the surface where it will be subjected to the maximum heat treatment. After inoculation the cans are closed, processed for the calculated time and temperature and then either incubated entire or sub-cultured and then incubated. The efficiency of the process is then a function of the number of cans or sub-cultures which show growth.

As an alternative to the methods used for calculating processes the procedure for checking the calculated process can be carried out at a number of different times and temperatures, the particular process which yields the most satisfactory results on incubation of the processed cans is then adopted. It is obvious that this method is of a hit-or-miss character and cannot, therefore, be recommended for general use.

In reaching a final decision on the time and temperature for a particular process the conditions under which the can and its contents are to be stored and the length of storage must be taken into consideration. If the cans are to be exported to hot climates or stored at high temperatures, for example, the process must be sufficient to ensure that the growth of thermophilic organisms will not occur.

The requirement in the Bigelow method[39] that the area under the lethality curve should be greater than unity to give an adequate process only applies to the particular organism for which the lethal rates have been determined. In practice it is usual to take the lethal rate for *Clostridium botulinum* as basis for calculation, but if more heat resistance organisms are likely to be encountered the total lethal effect of the process must be stepped up accordingly, and it is now common practice, in the case of certain packs which must be free of thermophilic organisms, to use a process with a total lethal effect of 7-8 compared to that required for the destruction of *Clostridium botulinum*, or alternatively to use a test organism of greater heat resistance such as referred to earlier in this Chapter.

Practical Applications

In the preceding paragraphs it has been shown how the processing time and temperature for a given canned food may be calculated from a knowledge of the thermal death time of a selected test organism and the rate of heat penetration to the centre of a can containing the food to be processed. In this study it has been demonstrated that there are many factors controlling the ultimate process to which a

given can of food must be subjected and that any considerable variation from standard conditions will result in losses due to bacteriological spoilage.

The most important factors under the control of the canner and which may lead to anomalous results if there is any great degree of variation are :—

    (1)   Time and Temperature of processing.
    (2)   Concentration of organisms present in the can before processing.
    (3)   Consistency of the can contents.
    (4)   Initial temperature of the pack.
    (5)   Coming up and cooling time.

Since the thermal death time curve obeys a logarithmic law, relatively small variations in temperature result in large variations in the time required for the destruction of spoilage organisms. For example, the thermal death time curve for *Clostridium botulinum* obtained by Esty and Meyer[4] shows that the time required for the destruction of the organism at 110°C. is just over three times that required at 115°C. It is, therefore, of vital importance that an accurate control of the processing time and temperature be maintained. The installation of recording thermometers and automatic temperature controllers as described in Chapter 8 enables a continuous and permanent record to be kept of every retort load processed and relieves the retort operator of the necessity of continuously watching his instruments and making adjustments to compensate for variation in the rate of heating.

The concentration of the spoilage organisms present in the filled can before processing is subject to considerable variations, but a great deal can be done in the cannery to ensure that the total number is kept at the lowest possible level, thus reducing the load on the process. There is often too great a tendency to ignore the initial contamination of the can contents and to rely on the process to destroy the spoilage organisms, rather than make efforts to reduce their initial concentration, and thus place less load on the heat treatment. This attitude cannot be too strongly condemned and is a frequent cause of the breakdown of a process which has been working satisfactorily, in addition, it often leads to the adoption of longer processing times than would be necessary if the initial contamination had been kept at low levels. Control of contamination starts outside the cannery with the control of the incoming raw material. Every effort should be made to ensure that the handling of the food before processing is carried out in such a manner as to avoid any undue addition to the naturally occurring contaminating organisms. The control of sanitary conditions within the cannery can also accomplish

a great deal in avoiding development of spoilage organisms. All filling, preparing, and processing equipment should be kept scrupulously clean and any "dead" pockets or corners where organisms can develop and multiply must be eliminated. Wooden equipment must be avoided, as it is often a potent source of contamination, and it should be replaced by metal. Where possible the routine cleaning should include the regular washing of the factory and cleaning of equipment at least twice daily.

Any variation in the consistency of the contents of the can will be reflected in a corresponding change in the rate of heat penetration to its centre. It has already been shown that the addition of starch has a considerable effect on the heat penetration; an example of this effect is the addition of thickening to the gravy in a meat pack thereby necessitating an increased processing time as shown in Fig. 71. Any change in formulation or the method of mixing must, therefore, be taken into consideration when deciding on the process to be adopted. Similarly, any variation in fill of the can may
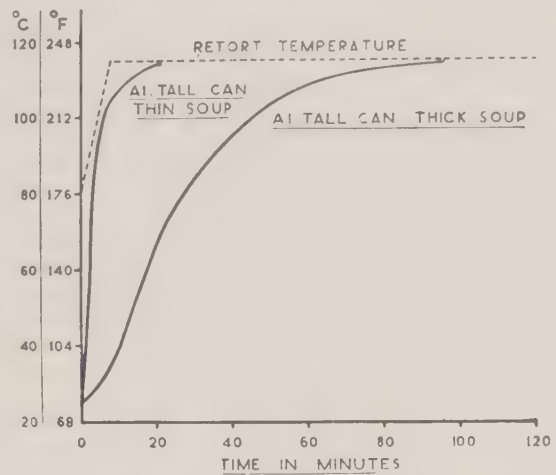
FIG. 71. Heat penetration curves for a thin and a thick soup, illustrating the marked change in the rate of heat penetration.

(*Courtesy "Food."*)

affect the rate of heat penetration and thus the total lethal effect of the process. Fig. 72 obtained by Lewis illustrates this effect and shows that the total lethal effect of the process is reduced by 14 per cent.

The initial temperature of the can before processing influences the total lethal
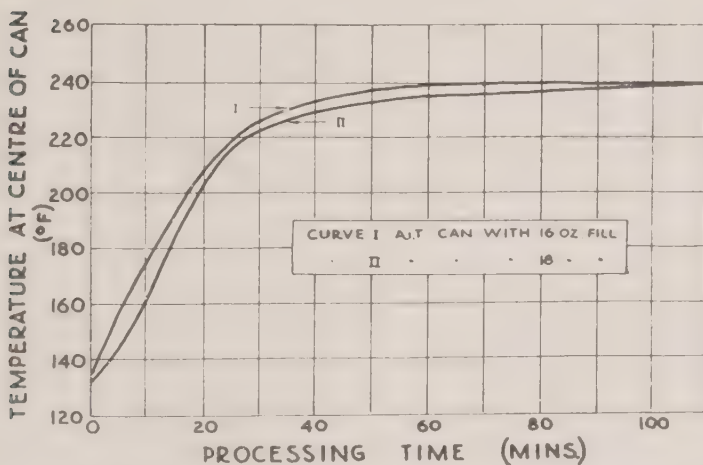
FIG. 72. Heat penetration curves illustrating the effect of variation in the weight of can contents on the rate of heat penetration.

(*Courtesy "Food."*)

effect of the process and it is now common practice to state the initial temperature in addition to the processing time and temperature; this is particularly necessary in the case of packs heating largely by conduction where the rate of heat penetration is slow. The filling and exhaust temperatures should, therefore, be accurately controlled, not only to ensure the production of an adequate vacuum, but also to standardise processing. It is also important to ensure that filled and closed cans are placed in the retorts and processed as quickly as possible, as any undue delay will result in a decrease in the initial temperature of the pack, and also an opportunity for the multiplication of the spoilage organisms contained in the can.

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CHAPTER 8

FILLING, EXHAUSTING, CLOSING, AND PROCESSING

Filling

IN packing all types of canned foods it is essential that the filling operation should be carried out accurately and uniformly in order :—

(1) To maintain a uniform headspace in the can.
(2) To ensure that the consistency of the pack remains uniform.
(3) To maintain a constant weight of product in the can.

Included in the term "filling" is the addition of liquids such as brine, syrup, gravy stock, etc.

The headspace in a can is important ; if too small, there is danger of the can ends becoming permanently distorted by the expansion of the contents during processing, while with products which are prone to develop hydrogen swells, there is insufficient space for the accumulation of any hydrogen which may be produced, with the result that the can ends will dome more readily than is the case with a normally filled can. Furthermore, if the container is overfilled, the consistency of the pack will be increased and the rate of heat penetration decreased. The total lethal effect of the process is thereby reduced and under-sterilisation may result.

Too large a headspace, on the other hand, results in an underweight can and a relatively large amount of air being entrained in the cans. It is common practice to fill the can within $\frac{1}{4}$in. to $\frac{3}{8}$in. of the top as measured across the flange of the unsealed can. It must be remembered, however, that the true headspace will be the above value less the depth of the countersink of the can which is about $\frac{1}{8}$in. to $\frac{3}{32}$in.

It is essential that the interior of the can be freed from dust and dirt before filling, for although the can maker does everything possible to ensure the delivery of clean cans it is extremely difficult to avoid the accumulation of foreign matter during storage. It has, for example, been shown that empty cans may contain micro-organisms ; salmon cans from a number of different factories were examined by Lang[1] and 1 per cent were found to contain spores of *Clostridium botulinum*. All cans should, therefore, be cleaned internally before filling. The ideal method is to arrange for cleaning to be carried out just before the filling operation and thus avoid re-contamination. High pressure steam or hot water jets are frequently used for this purpose and there are a number of machines available utilising one or both of these methods.

Filling may be carried out by hand or by machine, the choice of method being to some extent governed by the type of product to be filled ; delicate products such as asparagus, soft fruits, etc., are often not sufficiently robust to stand up to the inevitable friction and pressure accompanying mechanical filling.

In hand filling the cans are usually placed on a conveyor belt passing down the centre of a long table on either side of which are seated the workers engaged in the filling operation. The cans are either removed from the conveyor belt, filled and then replaced, or they are filled as they pass down the belt. In both cases frequent check weighings must be made to ensure that the correct fill is being maintained.

A semi-automatic filler, known as the hand pack filler, is sometimes used and illustrated in Fig. 73. With these machines 4 girls can fill up to 3,600 A2½ cans per hour.
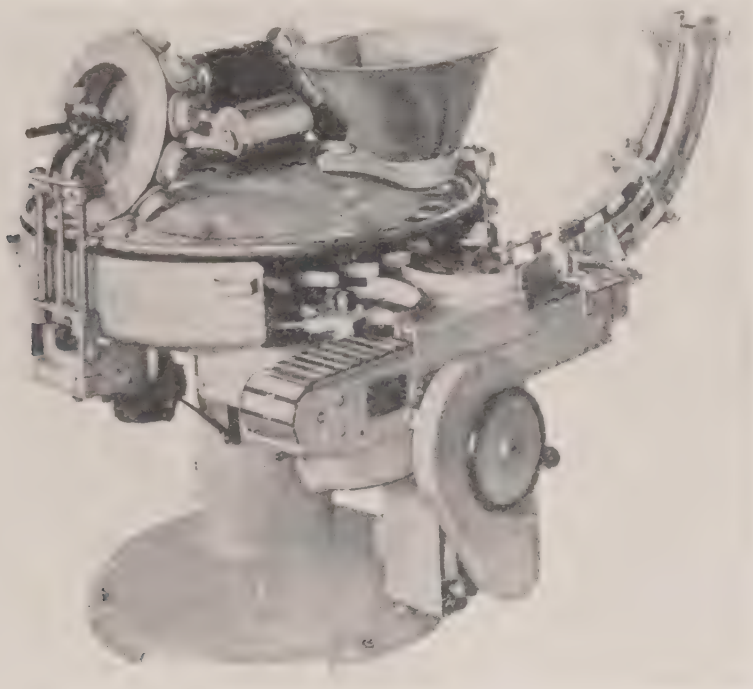
FIG. 73. Hand pack filler equipped with standard gravity hopper, and brushing, juicer, tamping, and agitator attachments.
(*Courtesy Chisholm-Ryder Co., U.S.A.*)

In the case of liquids and semi-solids, however, or where the product will resist mechanical damage, automatic filling machines are frequently used.

There are a number of types of automatic filling machines, many specially designed to satisfy a specific requirement. The chief desiderata of the ideal filling machine are :—

(1) The quantity filled shall be uniformly and accurately measured.
(2) There must be no spilling or drip, even when running at high speed.
(3) A no-can-no-fill device should be incorporated.
(4) Changing from one can size or quantity of fill should be a simple operation.
(5) The filler should be capable of handling a wide range of products.
(6) There should be no dead spaces in the filler where dirt and debris can accumulate and provide an opportunity for bacteria to accumulate and multiply. For the same reason all ancillary piping should be so arranged that food is not trapped in remote sections.
(7) All surfaces in contact with food should be made of non-corrodible materials, such as stainless steel or Monel metal.

The simplest products to fill mechanically are liquids and semi-solids, such as brine, syrup, milk, fruit juices, jam, soup, etc.

In packing fruit and vegetable products, syrup and brine are usually added not only to improve the flavour, but also to increase the rate of heat penetration and to exclude air from the interstices in the can.

The preparation of these two liquids is not always given the attention it deserves for if a clear and sparkling liquor is to be obtained care must be exercised in the selection of the solid raw materials and the water. It is essential to use stainless steel or glass-lined mixing tanks as any metallic corrosion may lead to undesirable results. Reference has already been made to the effect of hard water on the toughness of certain products such as peas, and also to the possibility of this effect being produced by impurities present in salt. It is, therefore, important to ensure that both the salt and the water used for making brine are free from calcium and magnesium salts. Iron salts are also particularly undesirable.

The sugar used in making syrup must be examined to ensure freedom from thermophilic bacteria which may cause spoilage, and also for sulphur compounds which are liable to accelerate corrosion of the can.

Both syrup and brine lines can be a potent source of bacterial infection if they are not properly and frequently cleaned, and it is convenient to have piping in detachable sections for this purpose and avoid "dead" spaces where liquid may accumulate. The composition of syrup and brine will vary with the product to be packed, it is customary, for instance, to add a certain amount of sugar to brine used for packing peas.

Cane sugar is usually used for the preparation of syrup as this tends

to produce a light coloured liquid ; on the other hand, there is reason to believe as stated in Chapter 3 that the use of beet sugar will, in certain cases, tend to reduce losses due to corrosion.

Both brine and syrup should be filtered before use and Cruess[2] advises that brine should be boiled to throw down thermally precipitable salts which may then be removed by filtration.

The strength of brines and syrups is usually measured by means of an hydrometer.

The simplest device for filling liquids capable of recirculation, such as brine and syrup, is a nearly horizontal pipe running just above the tops of the cans, the pipe being perforated at intervals. The liquid to be filled flows or is pumped from a storage tank, runs through the perforations in the pipe and so into the cans. The cans are filled to overflowing. The surplus liquor runs into a drain tank and is filtered and re-circulated. The headspace may be adjusted by inclining the cans at a predetermined angle thus allowing surplus liquor to escape. A device of this type is illustrated in Fig. 74. An alternative method
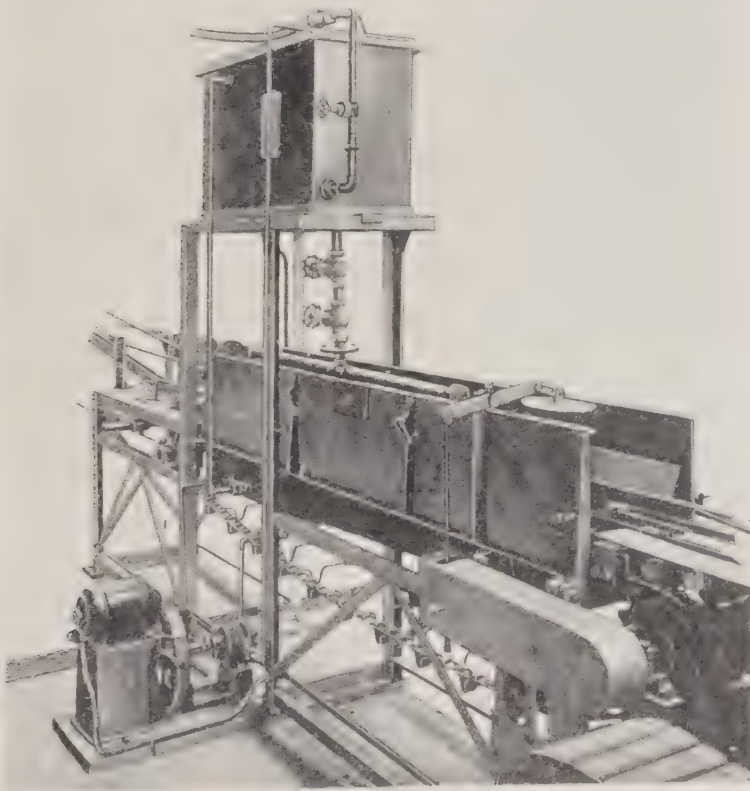
FIG. 74. Simple type of filler for liquids such as syrup. Adjustable guides permit the filled can to be tilted to any angle thus fixing the head space in the can.

(*Courtesy F. J. Ballard and Co. Ltd.*)

of adjusting the headspace is to push a plunger into each can thus displacing the requisite amount of liquid.

In plants where high daily outputs are required it is the practice to use one or other of the fully automatic fillers which have been developed for this purpose.

These machines may be divided into two classes: those which handle liquids and semi-solids, and those dealing with solids in particulate form such as peas, beans, tomatoes, plums, etc.

In the first class are included machines for brining and syruping as well as those for filling soups, condensed milk, jams, fruit juices and other products similar in character. This type of filler operates by one of two methods; either by means of a valve actuated by upward pressure from the flange or end of the can, or by filling a measured volume of the product into a chamber which is then brought vertically over the open end of the can and the contents discharged either by the force due to gravity or, in the case of semi-solid or sticky products, by means of a plunger or piston.

A typical machine of the valve delivery type is illustrated in Fig. 75. The amount of fill is controlled by adjustment of the filling valve which is so constructed that delivery is cut off when the contents of the can reach a pre-determined level. Machines of this type are suitable for all kinds of liquids, brine, syrup, thin soups and fruit juices.

In the plunger type of filler which is particularly suitable for filling such products as thick soups, pastes and pulps which flow less easily than thin liquids, the product is forced into a chamber, the capacity of which is adjustable to suit the volume
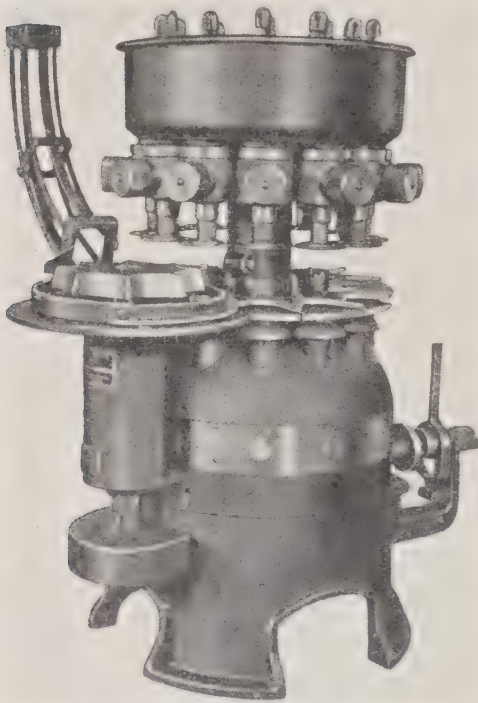
FIG. 75. 12-valve liquid filler suitable for filling free-flowing liquids.
(*Courtesy Food Machinery Corporation.*)

to be filled, and when full the contents of the chamber are discharged into the can. A filler of this type is illustrated in Fig. 76.

In addition to fillers designed for liquids and semi-solids much work has been carried out to develop machines for the rapid filling of solids, particularly such products as peas, beans, etc. In this field

also there are many different designs, the general aspects of which are illustrated in Fig. 77. The product to be filled drops from the hopper into the revolving pockets which then discharge their contents into the can.

It is common practice, where brine or syrup must be added, to couple a brine or syrup filler to the same machine. This attachment may consist of a revolving pocket plate, rotating inside the tank holding the liquid, the lower edge revolving under the liquid line while the upper edge revolves above the level of the liquid.

As the tubes in the pocket plate go into the liquid they are

FIG. 76. Plunger-type filler for filling liquid, semi-liquid or pasty materials. *(Courtesy Food Machinery Corporation.)*

filled and carried up to the top centre where they discharge their contents into funnels and thence into the cans. By this method the solid and liquid constituents of the pack are filled sequentially, an important advantage as the separate measuring of solid and liquid constituents will immediately indicate an underfilled pack, in contra-distinction to the method of filling to overflowing and then adjusting the headspace by tilting or other means, where an error in filling the solid part of the pack may pass unnoticed unless the can is weighed.

On some machines the liquid, although measured separately, is allowed to run into the can by the same funnel as the solid phase, the timing being so arranged that the flow of

FIG. 77. Eight-station filler for granular products complete with briner and brine storage tank. *(Courtesy Food Machinery Corporation.)*

liquid starts just before the solid and finishes just after. By this means the liquid assists the flow of the solid, a great advantage in the case of solids which are inclined to stick in the funnels.

Universal machines operating on the same pocket principle are made for filling such products as tomatoes, plums, mushrooms, apples, cherries, etc. The chief problem with these products, which are relatively large in size, is to avoid crushing and other mechanical damage.

The filling of some products has necessitated the development of special types of filling machinery, as in the case of corned beef, for example, where "stuffing" machines, as they are called, which force the meat into the can under considerable pressure, are used.

In the fish canning industry a considerable amount of hand labour is used in filling, as fish is a very delicate product which has frequently to be arranged in the can in a definite pattern, and no machine has yet been designed which is entirely satisfactory for the purpose. In salmon canneries, however, machines have been developed for filling salmon cuts at speeds up to 200 cans per minute. The machine also removes excess fish by means of rotating knives. A small quantity of salt is also automatically placed in the can before the fish is added.

The addition of oil to fish packs is accomplished by machines which inject a stream of oil into each can after they have been hand packed with fish.

Meat and fish pastes, meat roll and similar products are usually filled by the standard type of sausage filler consisting of a large cylinder at the bottom of which is a piston which rises and extrudes the meat through a filling nozzle whose diameter corresponds to the size of can to be filled.

In the filling of meat pastes and products of similar consistency the removal of entrapped air is important if a product of uniform texture and constant weight is to be obtained : a method of doing this is to use super-sonic vibrators by which means the filled can is subjected to very high frequency vibrations, thus driving out the entrained air.

The production of steak and kidney puddings and other products which require a lining of dough in the can has resulted in the use of an adaptation of pie making machines. With this machine an even lining of dough is deposited at the bottom and round the sides of the can. The dough lined can is then filled with the pudding filling and a disc of dough placed on top. It is usual to puncture several holes in the top disc of dough in order to permit the escape of air and other gases during the exhausting process.

In the filling of liquids through small apertures as is necessary with the vent-hole milk can, special filling machines such as the Dickerson

filler for evaporated milk are frequently used. This type of filler includes an attachment for automatically sealing the vent-hole with a spot of solder.

Exhausting

The object of the exhausting process is to remove air from the can and its contents, and thereby create a partial vacuum when the can is closed. It was originally thought that the vacuum so produced was one of the factors controlling micro-biological spoilage, but it has long since been recognised that it is not air *per se* which causes spoilage, but the organisms present in the air. It has, however, been suggested that the absence of air may inhibit the growth of certain aerobic organisms, but it is unlikely that this is a big factor in the case of canned foods. Air by reason of its oxygen content does, however, act as an accelerator of corrosion of the can, and its removal will, therefore, tend to reduce the rate of corrosion.

An extensive study of vacuum in canned salmon was made by Clark, Clough and Shostrum[3] and their conclusions may in general be applied to all types of canned foods. They stated that a vacuum is necessary for the following reasons :—

(1) To keep the can ends flat or concave.
(2) To reduce strains on the can during processing.
(3) To reduce the oxygen content of the filled can, and thus limit the corrosion of the metal container.

Cans with bulged or convex ends are usually regarded as unfit for consumption, as the bulging may be due to a number of causes, such as microbiological decomposition of the contents, hydrogen, produced by corrosion of the container, overfilling, or the effects of high temperatures and altitudes. As there is no means whereby the consumer can distinguish a microbiological swell from one due to corrosion of the container, for example, it is usual to reject all cans with domed ends, and although a can with flat or concave ends is not always free from spoilage, as, for example, in "flat souring," it is usually taken as an indication of the soundness of the contents.

Hydrogen swells are less likely to occur in cans with a satisfactory vacuum, and the effects of high temperatures and altitudes are also reduced.

The relationship between temperature and pressure in a closed can has been calculated by Chambellan, Cheftel, Thuillot and Boudeau[4] and studied quantitatively by Magoon and Culpepper[5] working with rigid metal containers. At the time of closure the pressure in the can is in equilibrium with the atmospheric pressure. When the can is closed and heated the pressure rises due to the increase in vapour

pressure of the contents of the can, the expansion of the solid and liquid contents, and the partial pressures of the air and liberated gases in the headspace. It will be seen, therefore, that the higher the temperature of closing the greater will be the final vacuum after processing and cooling. Thus, according to Magoon and Culpepper[5], cans sealed at 70°C. and 50°C. and then cooled to 20°C. will have a final vacuum of 12.3 inches and 6 inches respectively. The temperature of closing is, therefore, a factor of paramount importance in determining the final vacuum.

The increase in pressure which takes place in the closed can on heating may result in permanent distortion of the can and production of leaky seams. Magoon and Culpepper[5] have shown that a can closed at 80°C. develops a pressure of about 26.5 lbs. sq. inch at 121°C., but when closed at 50°C. the pressure developed will be about 30.7 lbs. sq. inch when heated to the same temperature (121°C.). The closing temperature is, therefore, also a vital factor in relation to the strain to which the can will be subjected during processing.

The vacuum in a can is a measure of the pressure difference between the atmosphere inside the can and that outside. Any reduction in atmospheric pressure will in effect reduce the vacuum inside the can. At high altitudes, therefore, where the atmospheric pressure is considerably reduced the ends of cans may bulge unless the cans showed a sufficiently high vacuum at normal levels. It is for this reason that a high vacuum is so important in packs which may be subjected to storage above normal altitudes.

The third reason for a vacuum is to reduce the oxygen content of the container, and as already shown in Chapter 3 oxygen plays an important role in accelerating the initial rate of corrosion of tinplate and any reduction in the oxygen present in the sealed can will, therefore, prolong the life of the pack.

The usual method of determining the vacuum in a can is by means of a vacuum gauge to which is fitted a hollow steel point protruding through a soft rubber gasket. In taking a reading the hollow point is forced through the can end, the rubber gasket making an airtight seal, and the vacuum is read off on the dial of the gauge. It is important when taking this reading to see that the hollow point does not become choked with the contents of the can and also to avoid depleting the end of the can by pressing too heavily on the gauge after piercing the can end. The pressure required to pierce the tinplate, therefore, should be relaxed before the reading is taken, only sufficient being used to maintain an airtight seal, otherwise too low a reading may be obtained.

An alternative method is to measure the vacuum which must be exerted on the outside of the can to cause one or other of the ends to

flip out. This method cannot be used to give an absolute value as it is dependent on the thickness of the tinplate forming the can and a number of other mechanical factors, but it provides a useful means of following the change in vacuum during storage or under varying conditions of temperature etc. In its simplest form the apparatus consists of a bell jar, from which the air can be exhausted, and a pressure gauge. The can is placed under the bell jar and the air gradually withdrawn until the can end suddenly flips out : the reading of the pressure gauge being taken simultaneously.

This method was used by Lueck and Brighton[6] in a study of the performance of various types of tinplate and blackplate containers, referred to in more detail in Chapter 12.

The final vacuum in a can is affected by many factors and these have been discussed at great length throughout the literature, and summarised by Clark, Clough, and Shostrum[3] as follows :—

(1) Time and temperature of exhaust.
(2) Exhaust with cans open or with clinched covers.
(3) Fill of the can and headspace.
(4) Delay between exhaust and closing.
(5) Loose or tight seams.
(6) Temperature at which vacuum is measured.

The time and temperature of the exhaust are probably the most important factors controlling the final vacuum. It has already been shown that a difference of $20°C$. in closing temperature may halve the final vacuum. The temperature of the headspace is also of considerable importance in determining the value of the final vacuum as the proportion of air in the water vapour-air mixture in the headspace grows less as the temperature of the headspace gases rises and it was for this reason that the process of clinching was adopted. Loosely clinched lids permit the free exit of steam and other gases during exhausting, and at the same time the lid is heated thus avoiding the sudden cooling of the headspace gases which would occur if a cold lid were placed on the can immediately before closing. The effect of clinching on the storage life of a number of canned fruits is shown in Table XIII after Hirst and Adam[7].

For a similar reason any delay in closing the can after exhausting must be avoided otherwise the advantages of clinching may be lost.

It has already been stated that increase in temperature of the closed can will cause an increase in internal pressure and it is important, therefore, that all vacuum readings should be taken at a uniform temperature or the values obtained corrected for any temperature variation. Clark, Clough and Shostrum[3] studied the

relationship between temperature and vacuum for canned salmon and their results show that cans for export to tropical climates should have a vacuum in excess of 9 inches if their ends are to remain flat at elevated temperatures, and a minimum vacuum of 12 inches is the standard which is normally adopted for these packs. This figure which is in excess of the 9 inches mentioned above provides an adequate safety margin for all cans. It is a safe general practice to arrange the exhausting operation to produce a vacuum of 12-15 inches for smaller cans and a slightly lower figure say 9-12 inches for the larger sizes. If too high a vacuum is obtained in the larger cans the sides of the can may be drawn in, a phenomenon known as "panelling."

<div align="center">

TABLE XIII

Effect of Clinching. All cans stored at 95°F.

(Hirst and Adam)

</div>

Fruit	Period to reach 25 per cent loss	
	Controls	Clinched
	weeks	weeks
Strawberries	18	27
Raspberries	20	25
Loganberries	18	23
White Cherries	39	51
Blackberries	27	33

The original method of obtaining a vacuum, and one which is still used in certain cases, is known as "brogging." By this method the can is sealed and heated until the contents are at a temperature of about 150°F., a small hole known as the "brog" hole is then made in one end or in the body of the can, and the internal pressure generated by the heating process is allowed to fall until it is in equilibrium with the outside atmosphere, the can is then resealed by soldering the "brog" hole and the heating process continued until the contents have been sterilised. An alternative method is to heat the can with an open "brog" hole and then seal and reheat as before.

Although this process is capable of giving satisfactory results it is uneconomical both in labour and time, and furthermore the resultant vacuum is subject to variations due to the inevitable time-lag between sealing the first and last cans of each batch.

The three principal methods now employed for exhausting a can are :—

(1) Heating the food before filling ; the hot food is then filled into the can and the can is closed before the contents lose heat.
(2) Heating the filled can, with or without the lid, and then closing.
(3) Closing the can in a chamber in which a high vacuum is maintained.

Little need be said with regard to the method of hot filling except to emphasise the necessity of ensuring that the temperature is sufficiently high to produce a satisfactory vacuum when the can is finally cooled. The method is often used in the packing of soups and other semi-liquid packs which are readily amenable to pre-heating and where texture is not easily destroyed by the inevitable stirring and mixing which must take place. It is important to ensure that the food is not maintained for an undue length of time in a semi-hot condition before sterilisation otherwise there is risk of spoilage, particularly by the development of thermophiles.

The method most used at present for exhausting is to pass the cans, with or without the covers loosely clinched on, through a heated chamber ; the time and temperature being so regulated that the centre of the can contents attains a temperature of 150°-190°F., depending on the nature of the pack and the size of the can.

An efficient exhauster must fulfil the following conditions :—

(1) Provide a constant and uniform temperature throughout its length.
(2) Avoid spilling the can contents especially where clinched covers are not used.
(3) Be free from jams and easily cleaned and inspected.

The simplest types of exhaust box consists of a narrow conveyor belt or wire running through a tunnel sufficiently large in cross-section to accommodate one can, an inlet and outlet for steam being provided at the ends.

Although this simple device is capable of giving excellent results, the throughput per minute is limited and it is, therefore, only used in small canneries.

Heat exhausting may be carried out either in hot water or in steam. It is held by some that hot water exhausting is more readily controlled than steam and causes less breakdown of tissue in delicate products such as berries and other soft fruits. On the other hand, in products where heat penetration is largely by conduction and the product not subject to breakdown, the additional heat provided by steam is a great advantage in obtaining an efficient exhaust.

In most cases a long exhaust at a relatively low temperature is preferable, particularly with products containing large quantities of

entrapped air, a better opportunity being afforded for the complete removal of the air than is the case with a short exhaust at a higher temperature.

If a long exhaust is to be adopted, it is essential that the exhaust box should have sufficient holding capacity to maintain output. The output per minute may be obtained by dividing the holding capacity of the exhaust box by the length of time of the exhaust.

One of the first and still frequently used types of hot water exhaust box is the disc type illustrated in Fig. 78. It consists of a heavy gauge mild steel tank which can be completely enclosed by means of covers which fit into channels forming a water seal and effectively preventing the escape of surplus steam. The cans are conveyed by a train of geared discs revolving in a horizontal plane; the water in the exhauster is heated by means of open steam coils. A variable speed gear can be fitted so that the time of exhaust may be varied at will. This type of exhaust box is used in many fruit and vegetable canneries where a relatively short exhaust is required.
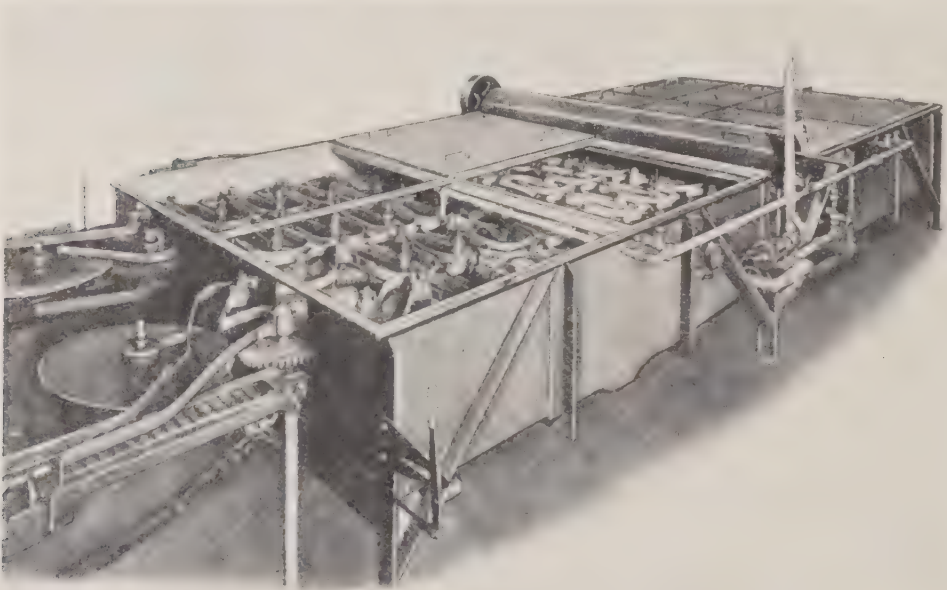
Fig. 78.   Disc-type exhauster with covers removed to show train of geared discs which convey cans through the exhauster.
(*Courtesy F. J. Ballard and Co. Ltd.*)

Although sometimes used as a hot water type of exhaust box, the chain or belt conveyor type is usually used with steam. There are many variations in the design of this type of exhauster but the basic principles are the same. A typical model is illustrated in Fig. 79. Heat is provided by means of open steam coils running above or below

the cans, and in at least one case, the steam coils are used as guide rails to divide the cans up into lanes and thus avoid the bunching which may sometimes occur with the normal arrangement.
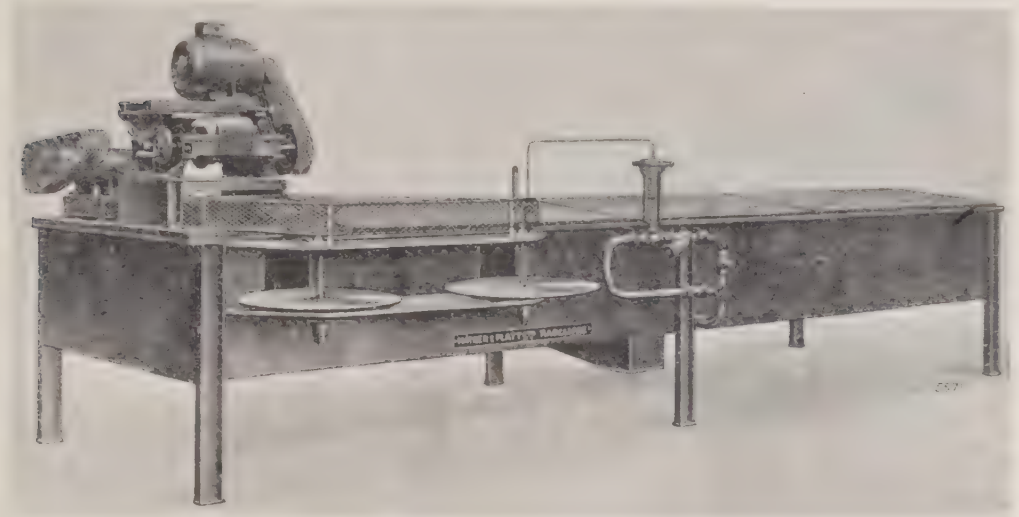
FIG. 79. Single tier exhauster.
(Courtesy Mather and Platt Ltd.)

One of the chief complaints against all types of exhausters is the amount of space they occupy, and several attempts have been made to design more compact models. One of the first was the circular type exhauster illustrated in Fig. 80. The five-way exhaust box illustrated in Fig. 81 is another attempt to achieve the same object. In this machine the cans are conveyed by means of parallel chains moving in opposite directions with rollers at each end to transfer the cans from one chain to another.

A further development in this direction was the introduction of the multi-tier exhaust box
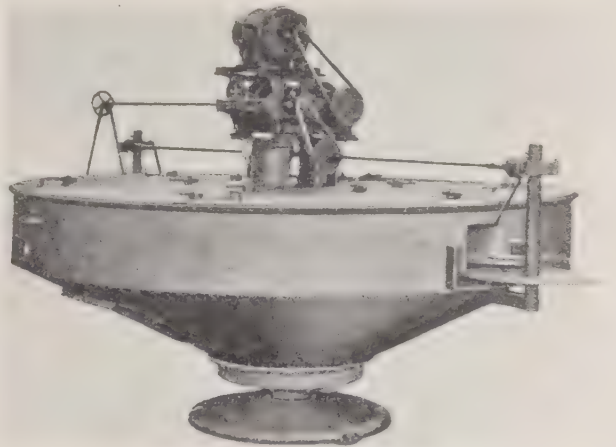
FIG. 80. Rotary exhauster fitted with motor and variable speed drive.
(Courtesy Food Machinery Corporation)

illustrated in Fig. 82. Heat is provided by open steam coils immersed in a shallow trough of water at the bottom of the exhaust box. The cans are conveyed by means of a chain conveyor.

the inlet and outlet consisting of the usual type of horizontal revolving disc.

Regardless of the type of exhauster, its main function is to heat the contents of the can to a temperature ranging from 150°-190°F., and as already emphasised, temperature is the all important factor in exhausting and it should, therefore, be adequately controlled to ensure that all cans are thoroughly exhausted.

Manual control of temperature needs the constant attention of an operator if it is
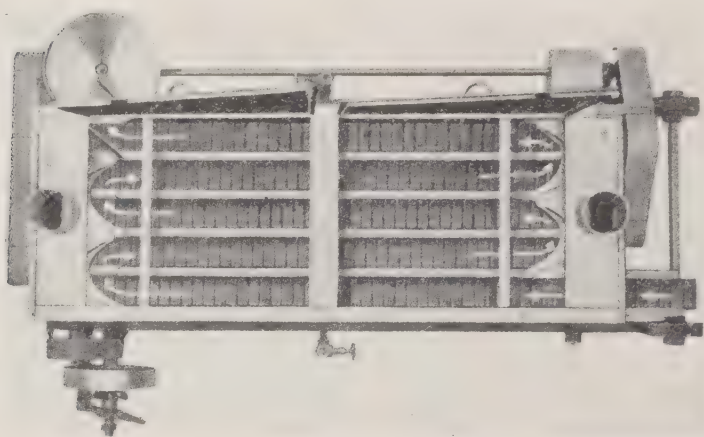
Fig. 81.   Aerial view of five-way exhauster illustrating path of travel of cans.
(*Courtesy Berlin Chapman Co.*)

to be efficiently and accurately maintained, and automatic control has much to recommend it. By this type of control fluctuations in steam supply and load conditions are automatically compensated,
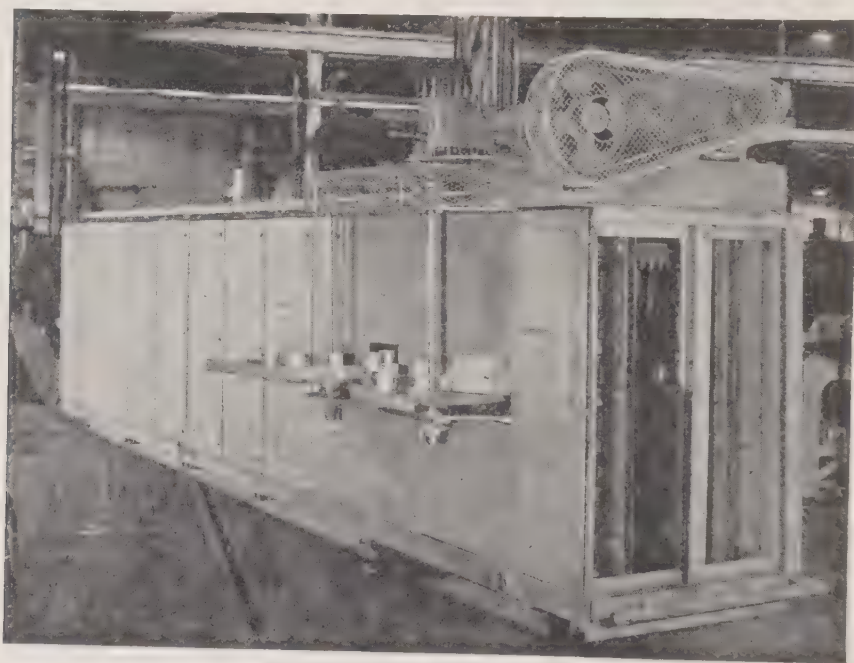
Fig. 82.   Multi-tier exhaust box with end removed to show interior.
(*Courtesy Mather and Platt Ltd.*)

thus saving considerable quantities of steam and avoiding under or over-exhausting. Furthermore, if a temperature recording instrument is fitted a permanent record of all exhausting processes is available at all times for reference.

A typical set up for a long exhauster is shown in Fig. 83 after Schmid[8]. Here two temperature controllers are fitted, and the exhauster divided into two heating zones. The same author suggests that in exhausters up to 15 feet in length satisfactory results will be obtained with one controller placed about a third of the way from the inlet end, while with exhausters over 15 feet in length two controllers should be used as illustrated.

In some canneries not equipped with proper exhaust boxes, or where the time of exhaust is unduly long, retorts are frequently used, the cans with clinched covers being placed in the retort which is then held at about 2-3 lb. pressure until the centres of the cans have reached 150°-190°F. The cans are then removed from the retort, closed and processed. This method is capable of giving good results and provided the pressure is reduced gradually at the end of the heating cycle no excessive loss of can contents will occur.
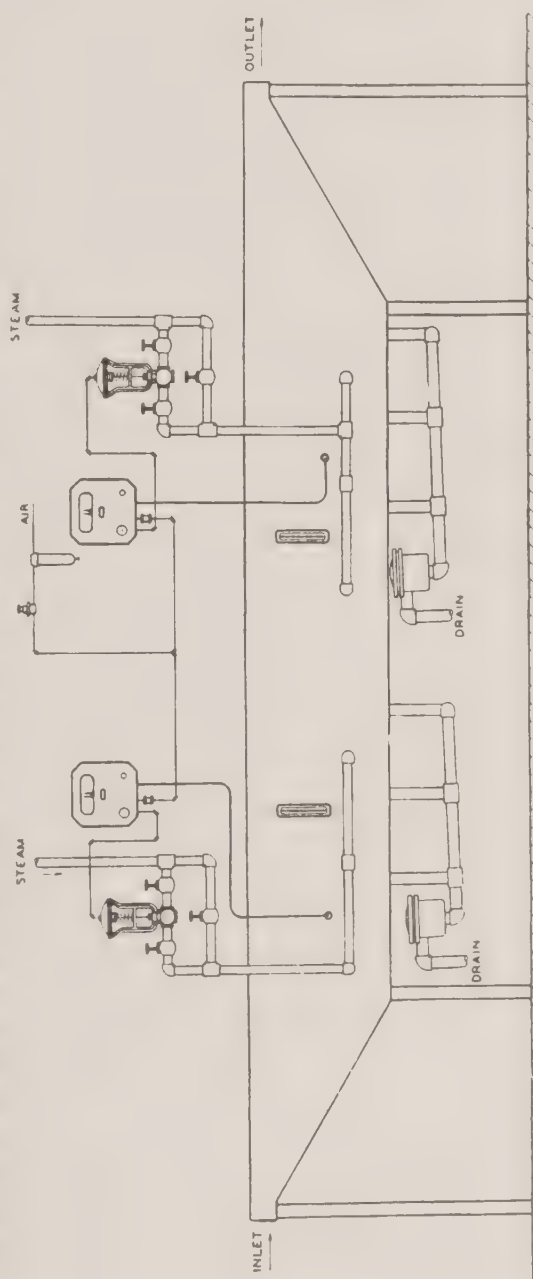
Fig. 83. Exhauster fitted with temperature controllers. The length of the exhauster being divided into two heating zones to enable incoming cold cans to be brought up to temperature as rapidly as possible by maintaining the first section of the exhauster at a higher temperature than the second section.

(*Courtesy Taylor Instrument Co.*)

It is, however, open to some of the same objections as "brogging" as there must necessarily be a time lag between removing the cans from the retort and closing the first and last cans in any batch.

Furthermore it is wasteful both of retort space and labour used in loading and unloading retorts.

The final method of exhausting cans, and one which is finding increasing application, is to close the can in a chamber from which the air has been previously withdrawn. There is nothing new in this method as it has been adopted for many years in the production of corned beef and similar products. It is, however, only during the last few years that the vacuum closing of sanitary cans has been adopted on a large scale. The process cannot be readily used for packs containing a high proportion of occluded air as the time required to remove this air slows production to uneconomical levels.

Although vacuum closing effects a saving of time in exhausting, the fact that the can is closed cold necessitates an increase in the processing time as compared to the can which is heat exhausted.

The original type of vacuum exhauster consisted of a chamber from which the air could be removed, and a device for sealing by means of solder the small hole which was punched in the top of the can to allow the escape of air. The apparatus frequently took the form of a chamber shaped like a ring.

This apparatus has now largely been superseded by the modern high speed vacuum closing machine. The cans pass through a valve into a chamber from which the air can be removed, and the can lid is double seamed while the can is held in the evacuated chamber, the vacuum drawn on the chamber being of the order of 23-26 inches. The final vacuum attained after processing will always be less than that immediately after vacuum seaming owing to the production of gases and the release of entrapped air from the can contents.

Closing the Can

Unless the can is hermetically sealed before processing all the care taken in preparation and sterilisation will be wasted and the contents of the can spoiled. The efficient performance of the closing operation is therefore a matter of vital importance to the canner, and as spoilage organisms may be as small as 1/250,000 inch in length, the necessity of ensuring that the can seams are perfectly formed becomes readily apparent.

Open Top Cans. Can makers reach such a very high state of perfection in the production of cans and also maintain an efficient servicing organisation that some canners tend to take seaming efficiency as a matter of course and pay too little attention to the performance of this all important operation.

The importance of the regular and frequent checking of can seams during production cannot be over-emphasised ; samples taken every 20 minutes should be examined in the case of machines which are running continuously, while about one can in every thousand should be examined from machines which run intermittently. Any departure from standard seam dimensions will then be quickly spotted and the fault rectified before the trouble becomes too widespread.

Cans were originally made by hand and all seams were soldered ; machine made cans then displaced the hand made variety, and these in turn gave way to the modern open top type of can where the only solder used is on the side seam. The end seams depend on the mechanical perfection of the two interlocking hooks formed during the seaming operation, plus the presence of a thin film of lining compound. A bad seam may result in the leakage of air into the can and the introduction of spoilage organisms ; it may also permit the ingress of cooling water which may be contaminated with spoilage organisms. Scott[9], for instance, showed that chlorination of cooling water reduced spoilage of canned corn by 5 to 7 times when compared with cans cooled in untreated water.

Double seaming machines vary considerably in design and speed of operation, but all have four units in common which are essential for the formation of the double seam :—

    (1)   First operation seaming rolls.
    (2)   Second operation seaming rolls.
    (3)   Baseplate or can lift.
    (4)   Seaming chuck.

The first and second operation seaming rolls are made from hardened alloy steel and are so shaped that the first operation roll tucks the started edge of the can end under the flange on the can body, forming an almost cylindrical bead ; the second operation roll then flattens this bead forming an airtight seal. The baseplate or can lift supports the can and lifts it so that the countersink in the end to be seamed engages in the seaming chuck.

The dimensions of the finished seam will vary slightly between can manufacturers, and also with the thickness of the tinplate used in can fabrication, but the measurements quoted by Baumgartner[10] may be considered typical :—

    Length : not greater than 0.125 inches.
    Countersink : 0.125 inches.
    Body Hook : 0.075-0.085 inches.
    Cover Hook : 0.075-0.085 inches.

An idealised cross section of a seam together with an explanation of the more important dimensions is shown in Fig. 84.

Although a seam may deviate from the ideal measurements given above, and still remain airtight, the possibilities of loss are greatly increased and adherence to standard dimensions gives the greatest possible margin of safety against damage caused by blows, rough handling and the like.
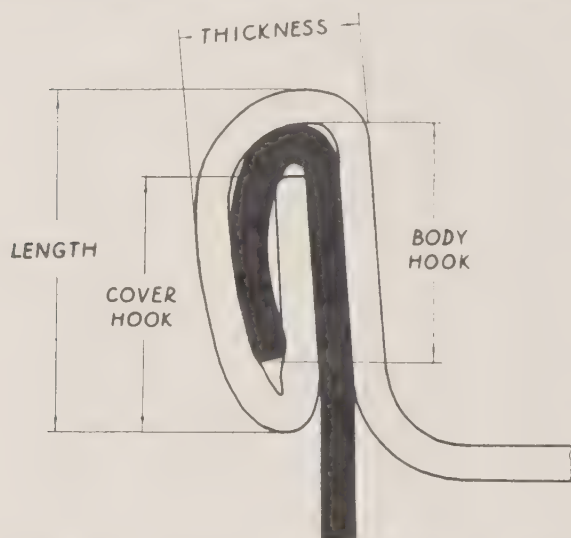
FIG. 84. Diagrammatic cross-section of double seam showing main dimensions.
(*Courtesy Dewey and Almy Chemical Co.*)

The contours of the seaming rolls are of paramount importance in determining the shape of the finished seam and it is, therefore, essential that they should be frequently checked and returned for regrinding when they commence to show signs of wear. Enlarged diagrams of the ideal contours are shown in Fig. 85.

The height of the first operation roll should be so adjusted that the roll just passes over the upper edge of the chuck. It should just turn freely and not rub hard enough on the chuck to cause wear, but there should be no space between the flange of the seaming roll and the upper edge of the chuck, otherwise the metal of the can cover will be rolled over the edge of the chuck and a "cutover" may be produced. To set the rolls the proper distance from the chuck face the seaming machine manufacturers provide test wires, the thicker wire for the first operation. These wires are inserted between the roll groove and the chuck face. The rolls should be set so that a slight pressure is required to insert and remove the wires; the rolls should not be adjusted to grip the wire so that removal is difficult.

FIG. 85. Ideal contours for seaming rolls. first operation (left) and second operation (right)

(*Courtesy Dewey and Almy Chemical Co.*)

When the first operation roll is adjusted an empty can should be put through the machine and the first operation seam, so produced,

examined. The metal of the can cover should be well tucked under the flange on the body and an almost round bead formed. The bead should not be so tight as to be almost solid. A cross section of a typical normal first operation seam is shown in Fig. 86.

If the first operation is satisfactory a similar procedure is adopted for the adjustment of the second operation roll. Although the test wires are useful in obtaining the correct adjustment they should not be depended upon for the final adjustment. Visual inspection and measurements of a completed seam should be made. The appearance of a normal seam is shown in Fig. 87.
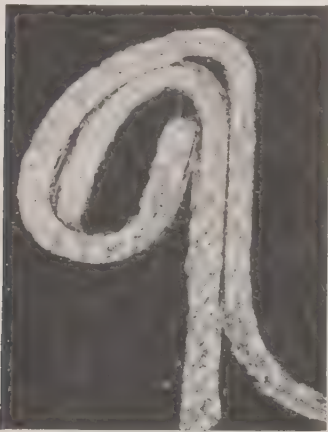
FIG. 86. Cross section of normal first operation seam.
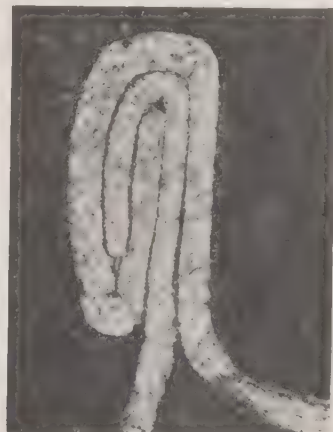
FIG. 87. Cross section of normal seam after second operation.

(Courtesy Dewey and Almy Chemical Co.)

It has already been stated that the regular and frequent checking of the dimensions and appearance of the double seam is essential for the maintenance of a high degree of seaming efficiency. It is important that a complete check should be made, the seam should be judged not only by its external measurements, but also by measurements made after dissection. It is perfectly possible, for example, to produce a seam with external dimensions within the permitted tolerances and yet it will leak.

Before the seam is dissected its length, width and the depth of countersink should be measured and recorded, and a general note made of the appearance of the seam. The seam should, for instance, be pinched quite tightly against the body of the can and the contour generally follow that of the groove in the second operation roll. The upper corners of the seam should be slightly curved with a distinct flattening between them caused by pressure of the seam against the upper face of the groove in the second operation roll.

Seam gauges are provided by the can makers for the checking of seam measurements. Limits are indicated by means of "go" and "no go" slots. In one type of gauge the slots marked .075in. and .085in. are the upper and lower limits of the can-body hook. The slot marked .125in. represents the maximum length of the completed seam and is marked "go" on the reverse side of the gauge: this slot should just slip over the completed seam. The slots marked .060in., .0625in. and .065in. are for measuring the width of the completed seam and the extension at the end of the rule marked .128in. is the upper limit for the depth of the countersink. Apart from defects due to departure from standard seam dimensions two other common faults which can be observed by inspections are "spurs" and "cut-overs."

Spurs are formed when the action of the seaming rolls fails to tuck the cover hook completely under the body hook and may occur at several points around the circumference producing a projection at the base of the seam as shown in Fig. 88. and which in many cases is a source of leakage.

FIG. 88.   Enlarged view of a spur.
(*Courtesy Mr. J. G. Baumgartner*)

Cut-overs are sharp edges produced on the inside of the top edge of the seam and are most noticeable at the point where the lap is rolled into the double seam. In extreme cases the metal may be cut completely through.

This defect is produced by too much baseplate pressure, too much clearance between seaming rolls and the upper face of the seaming chuck, and also by too much first operation pressure.

A further source of trouble in seaming may be the use of cans with bent or cracked flanges. Flange rectifiers are supplied by can makers to facilitate the straightening of damaged flanges and such cans should not be used until this process has been carried out.

Cans with cracked flanges should not be used as they will almost certainly leak.

A seam may be dissected for inspection by two methods. In the first method a file cut is made completely through the double seam avoiding the side seam ; the first thickness of tinplate is filed through all round the seam, then by tapping the outer edge of the filed section with the file it will be found that the remains of the cover hook can be removed. The relative ease of this operation also gives an indication of the tightness of the seam. The inner side of the cover hook and the body hook can now be inspected and measured.

In the second method of seam dissection the end of the can is cut out with the exception of about ⅜in. all round the circumference. A radial cut is now made completely through the double seam and the remainder of the can end. It will now be found possible to peel off the remainder of the can end which breaks away at the top of the double seam thus allowing the body and cover hooks to be separated as described in the first method of seam dissection.

When the can and body hooks have been disengaged by one of the two methods described above they should be measured by means of the seam micrometer and compared with the standard dimensions already given. The cover and body hooks should be examined for wrinkles caused by looseness of the seaming rolls. An arbitrary scale has been adopted to act as a measure of the degree of wrinkling. This may range from 0 to 10 as shown in Fig. 89 after Blake[11], or more
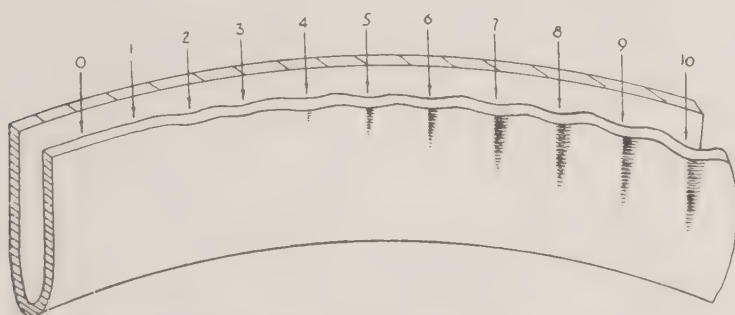
FIG. 89. Diagram of method of wrinkle rating in which absence of waves rates as zero and a full width wave as 10.
(Courtesy Dewey and Almy Chemical Co.)

simply, from 0 to 5 as adopted by most can makers. On the latter basis a wrinkle value of 1 would signify a wrinkle extending 1/5 the

length of the hook under examination, and a value of 3 a wrinkle extending 3/5 the length of the hook, etc.

Excessive wrinkling prevents the formation of an air tight seam and is a potent source of spoilage.

In measuring the cover and body hooks a series of at least four readings should be taken at various points on the circumference in order that any variation round the circumference of the seam may be detected. The portion of the seam opposite the side seam will usually show any fault in seaming before the remainder of the seam owing to the two additional thicknesses of metal which are of necessity rolled into it.

To make a detailed study of can seams an inspection of a cut and polished section of the seam *in toto* is necessary. A method of obtaining such sections has been given by Stevens[12]. The polishing technique is similar to that commonly adopted in standard metallographic practice, the seam cross section being embedded in suitable material before polishing.

Assuming the contours and surfaces of the seaming rolls and chuck are in good condition and the cans and ends are satisfactory there are only four variables controlling the formation of the double seam, namely :—

(1)   Baseplate pressure.
(2)   First operation roll pressure.
(3)   Second operation roll pressure.
(4)   Height of seaming rolls in relation to the seaming chuck.

An extensive study of the effect of seamer adjustments on the contours and dimensions of the double seam has been made by Blake[11] in which all possible variations of baseplate and roll pressures were considered. The resulting series of 54 photomicrographs of seam sections show in a graphic manner the effects produced by the many varying sets of conditions.

It is difficult to generalise on the effects of the various adjustments as they are to a great extent interdependent, but the following may be considered the basic functions of each component of the seaming machine : The baseplate pressure controls the length of the body hook and, therefore, the length of the can. Excessive baseplate pressure produces too long a body hook and a tendency to form "cut-overs."

The first operation rolls play a large part in determining the size of the cover and body hooks and excessive looseness of this operation may fail to turn the cover hook properly under the body hook and a seam with a short cover hook may result. The effect of variation in

the first operation roll pressure are well shown in Fig. 90. Excessive tightness at this operation will produce a long seam and a tendency to form "cut-overs."

The second operation flattens the rather round seam produced by the first operation rolls and squeezes the various layers of metal together forming an airtight seal. Looseness of this operation will result in a seam with incorrect contours and rounded upper edge, the hooks will usually separate easily and frequently show excessive wrinkling. Excessive pressure of the second operation on the other hand tends to produce a long seam and the base of the seam may be squeezed to such an extent that a lip is formed.

The desiderata of a good seam, therefore, are that it should conform to the standard dimensions already given, the body and cover hooks should be well interlocked and free from wrinkles, the contour should be uniform along the circumference and conform closely to that of the second operation rolls, and the top of the seam being somewhat flattened.
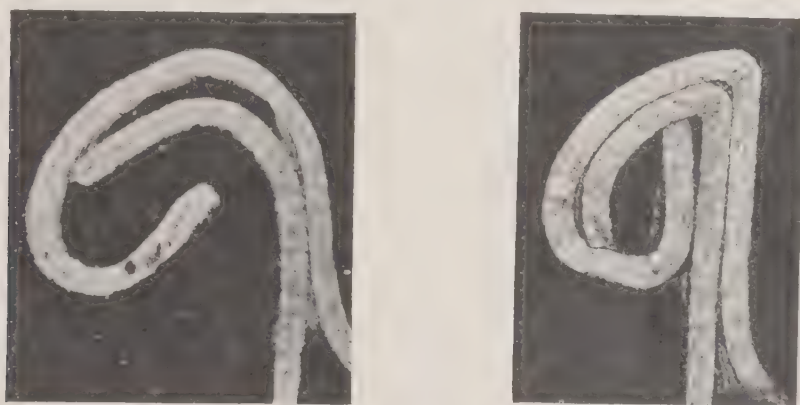
FIG. 90. The effect of variations in first operation roll pressure, loose (left), and tight (right). This should be compared with Fig. 86. (*Courtesy Dewey and Almy Chemical Co.*)

Soldered Cans. In addition to the round open top type of can, mention must be made of the fully soldered type used for packing milk. These cans are supplied to the canner with both ends soldered on, the cans being filled through a small hole in the centre of one end. This filler hole is soldered by the canner at speeds up to 190 cans per minute by a soldering device attached to the filling machine. The cone shaped soldering bit rotates continuously and at the same time reciprocates vertically and laterally remaining in contact with the cans for a short time as they travel through the seamer. The bit is heated by a gas flame which heats the top of the rotating cone. Care is needed to ensure that the edges of the hole to be soldered are quite

free from milk and blasts of superheated steam are sometimes used for this purpose.

Miscellaneous Types of Can. The above description of methods used in closing cans has been confined to round cans, but there are a variety of other shapes such as the oval cans used for fish, the rectangular cans used for corned beef and other meat packs, etc. The general principles of seaming remain the same, however, no matter what type of double seam is made, but in the case of irregular cans added care is necessary due to the sudden change in radius which occurs at the corners of the cans.

Processing

Together with can seaming, processing is the most important operation in canning and it has, therefore, been the subject of a great deal of investigation since the inception of the industry. The two chief objects of the process are :—

(1) The destruction of the spoilage organisms which may be present in the hermetically sealed container.

(2) The cooking of the food in the container to render it palatable and attractive in appearance and texture.

Of these, the first is the most important, but it must not be forgotten, particularly with fruit and vegetable products, that processing in excess of the time required for the destruction of the spoilage organisms will, in most cases, result in a deterioration in quality and palatability of the can contents.

The principles of the processing operation and the methods by which the time and temperature of a process are determined have been dealt with in Chapter 7 and the present section of this Chapter will be devoted to the practical application of these principles.

Canned foods may be divided into two classes as far as processing is concerned ; those which may be sterilised at or below 212°F., and those which necessitate temperatures in excess of 212°F. In the first class are found nearly all fruits and a number of acid vegetables, while in the second class, are the non-acid vegetables, soups, meats and meat products, fish, milk, etc.

The fact that temperatures above the normal boiling point of water are necessary for many products resulted in the early adoption of the retort or pressure cooker. Even before this time, however, it was the practice to add common salt or calcium chloride to the open tanks in which the filled cans were heated and thus obtain a higher temperature, sometimes as great as 240°F. The chief drawback to this method was the frequency with which explosions occurred due to the high pressures developed in the heated cans.

It was not long, therefore, before the retort or pressure cooker was adopted for the processing of all products at temperatures above 212°F.

Present day processing equipment may be conveniently grouped under the following headings :—

    (1) Batch type Open Cookers.
    (2) Continuous Open Cookers (Still).
    (3) Continuous Open Cookers (Agitating).
    (4) Batch type Retorts (Still).
    (5) Batch type Retorts (Agitating).
    (6) Continuous Pressure Cookers (Still).
    (7) Continuous Pressure Cookers (Agitating).

Batch Type Open Cookers. This represents the simplest equipment for the sterilisation of products at temperatures up to 212°F., and consists of a round or rectangular tank heated by means of open or closed steam coils. The cans are placed in crates which are then lowered for the requisite time into the water filled tank which has previously been heated to the processing temperature.

This method is still used to some extent in small canneries where high outputs are not required.

Continuous Open Cookers (Still). This type of cooker was a logical development of the cooker described above. Originally it consisted of a long tank containing water heated by closed or open steam coils, the cans being conveyed through the tank by means of an overhead conveyor at such a rate that they received the amount of heat necessary to sterilise their contents. The fact that the tank was open to the atmosphere resulted in considerable wastage of steam, and in addition, made the control of temperature somewhat difficult.

An improved cooker of this type is now available and is used for the processing of delicate fruits such as strawberries, loganberries and similar products which may break down if agitated, producing broken fruit and cloudy liquor. An example of this type of cooker is illustrated in Fig. 91. It consists of a totally enclosed tank, steam being produced by heating a bath of water at the bottom of the tank.

Continuous Open Cookers (Agitating). Although several products are better processed without agitation, a large number, especially those heating by convection, can be more satisfactorily sterilised if agitation is employed. The effects of agitation and the type of products for which agitation is desirable have already been considered in Chapter 7.

The use of the word "open" is a survival of the time when open tanks were used for processing at atmospheric pressures, and present day "open" cookers are usually fully enclosed, thereby reducing steam
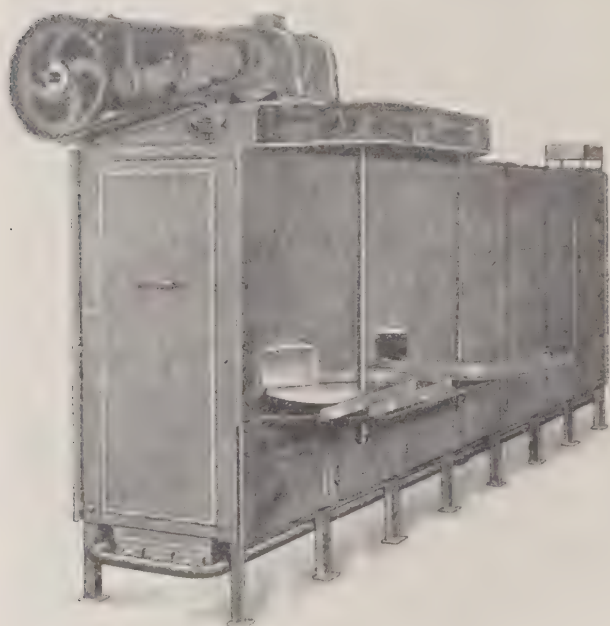
FIG. 91.   Continuous non-agitating multi-tier cooker.
(*Courtesy Mather & Platt Ltd.*)

consumption and preventing undue evaporation of water.   The term "open," therefore, has come to signify processing at atmospheric pressure.   A typical agitating open cooker is illustrated in Fig. 92.
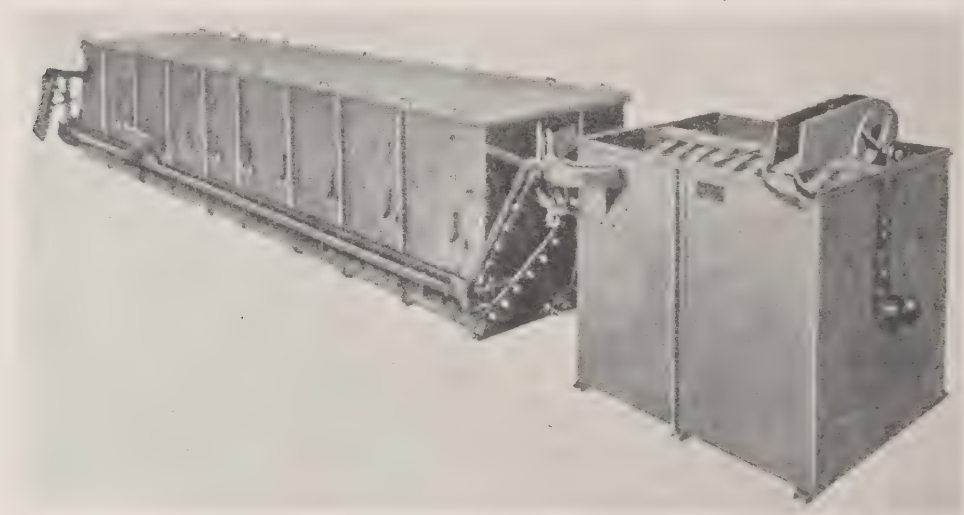

FIG. 92.   Variable discharge cooker and cooler.
(*Courtesy Food Machinery Corporation*)

The cooker consists of an enclosed tank containing a fixed spiral and a cylindrical reel revolving inside the spiral.   The cans enter a small porthole at one end of the cooker and travell aong the spiral. Cookers of this type may be divided into two classes ; those with

variable inlets and those with a variable outlet. The length of the process is controlled by selection of the porthole through which the cans enter or are discharged, the revolving reel being allowed to run at constant speed. Variable inlet cookers are recommended for speeds in excess of ninety cans per minute.

The complete installation consists of a cooker and cooler combined. The cooler consisting of a rather shorter version of the cooker.

The design of these cookers has varied from time to time, the original being a rectangular tank which later gave way to a cylindrical tank, while the present trend is to a straight sided tank with a round bottom such as that illustrated in Fig. 93.
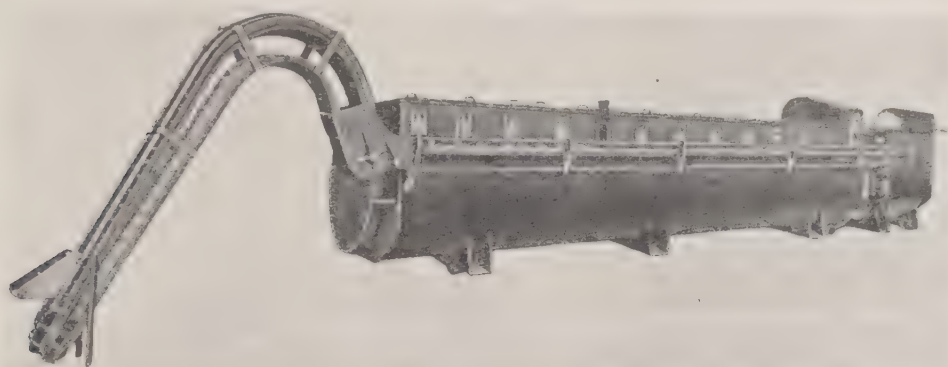
FIG. 93. Continuous variable inlet round bottom cooker and cooler. (*Courtesy Food Machinery Corporation*)

Processing may be carried out either in steam or in water, both methods having their adherents, but the water method permits a wider range of temperature to be obtained, and by the use of a temperature controller it can be maintained at 2°-3°F. below the boiling point, thus saving an appreciable amount of the heat which is inevitably lost if water is maintained at its boiling point in an open vessel.

In purchasing a cooker of this type, or any piece of apparatus working on a continuous output, it is important that the output should be synchronised with the rest of the apparatus in the line. The output of a continuous cooker may be calculated by dividing the number of cans which are required to fill the apparatus by the length of the process in minutes, the result being the output per minute.

Batch Type Retorts (Still). This represents the simplest type of equipment for processing those products which require a temperature in excess of 212°F., and is used extensively in canneries which by reason of their varied output demand great flexibility in processing conditions.

There are two basic forms of this retort : vertical and horizontal, each variety having its own minor differences.

The vertical retort is cylindrical in cross section and is usually operated in a straight row or in a circular battery of several retorts, but whichever system is adopted an overhead travelling hoist is necessary for loading the crates of cans into the retort. It is a common practice to sink vertical retorts beneath the floor level and thus reduce the distance through which the retort crates have to be lifted. The horizontal retort is sometimes made square in cross section, but the present tendency is towards larger horizontal retorts of cylindrical section. Where a high rate of output is required doors are provided at both ends of the retort so that the bogies of processed cans are pushed out of the retort by the incoming bogies of unprocessed cans.

The advantage of horizontal retorts is that cans for processing may be loaded into crates placed on bogies which are then run on rails into the retort thus avoiding the lifting necessary with vertical retorts. In an effort to speed production by reducing the time lost in securing the doors of horizontal retorts, locks operated by turning a large hand-wheel in the centre of the door have been developed.

With all batch type retorts it is important that the size should be so chosen that the time of loading is kept as short as possible and in any case should not exceed 30 minutes. If the loading period is excessive there is a risk that heat exhausted packs will cool down and thus reduce the lethal effect of process. Spoilage organisms will also have an opportunity to multiply if the filled cans are held for an undue length of time before processing and an increased load will be imposed on the sterilising process.

Retort Operation. The medium used for heating the retort is almost universally steam, although water is sometimes used.

The production of canned foods of uniform quality and flavour is, according to Ball[13], only possible if the following conditions are fulfilled :—

(1) Every container receives the same treatment.
(2) The retort is heated rapidly to its holding temperature.
(3) The processed containers are cooled rapidly.

In order to implement the above conditions it is essential that the retort be equipped with the necessary recording and measuring instruments to enable the operator to maintain a continuous check on processing.

The National Canner's Association Research Laboratories have recommended[14] that all retorts should be equipped with :—

(1) Controller. An automatic controller to maintain the specified temperature of the retort.

(2) Indicating Mercury-in-glass Thermometer. The fitting of two such thermometers is advised, one to act as the official temperature guide for the operator and the other to act as a check instrument, the bulb of the latter instrument being placed in close proximity to that of the temperature controller.

(3) Recording Thermometer. The charts from this instrument are a permanent record of the processing conditions of each batch.

(4) Pressure Gauge. The main essential of this gauge, in common with all other instruments, is that the dial should be sufficiently large as to be easily readable at a reasonable distance.

(5) Lighting. A point too often forgotten when installing instruments is to ensure that the dials and gauges are so placed that they can easily be read at all times of the day and night.

(6) Valve Controlled Vents. It is important to see that the vents are of sufficient size to ensure adequate venting of the retort.

(7) Bleeders. In addition to bleeders for thermometers, 1/8in. bleeders are necessary and they should be open and emit steam freely during the entire process.

(8) Drain Valve. This valve should be of sufficient size to permit the rapid removal of water after cooling.

(9) Steam Line. The steam line should lead to a perforated pipe within the retort. The perforations being so arranged that even distribution of the steam is obtained.

(10) By-Pass. In the event of the automatic controller breaking down, a by-pass round the controller will permit the retort to be operated by hand and thus avoid loss of output.

(11) Safety Valve. A safety valve is necessary to prevent the development of excess pressure.

The above suggestions are based on practical work extending over a number of years and a study of the fundamental principles involved in processing in batch type still retorts.

The efficiency of steam as a medium for heat transfer depends upon its high latent heat (970 B.T.U.'s per pound) and the fact that when steam condenses the latent heat is released and transferred to the surface on which the steam is condensing, in this case the cans being processed. Air, however, does not exhibit these properties at the temperatures under consideration and may in fact act as an insulator, the complete elimination of air from retorts by adequate venting is, therefore, vitally important. Apart from the insulating effect of air the presence of air or any other gas mixed with the steam lowers the temperature of the steam due to the fact that its temperature is dependent on its partial pressure. For example, in a mixture of steam and air at a gauge pressure of 15 lb./sq. in. in the proportions of one of

air to two of steam, the air will exert a partial pressure of 5lb./sq. in. and the steam a partial pressure of 10 lb./sq. in. The heat in the mixture comes from the steam only, the temperature being equivalent to steam at a pressure of 10 lb./sq. in. or 228°F. instead of 250°F. as would be expected from the reading of the pressure gauge.

It is, therefore, extremely important to ensure that all air is removed from the retort during the coming-up period by adequate venting. It was at one time common practice to recommend that retorts should be vented until the pressure gauge and temperature readings reached corresponding values, but in an extensive study of the problem Somers[15] has shown that this method is unreliable if pockets of entrapped air are left in the retort, as these areas will tend to remain at a lower temperature than the rest of the retort, although, the pressure temperature relationship may be satisfied. An example of this phenomena is illustrated in Fig. 94 after Somers[15],
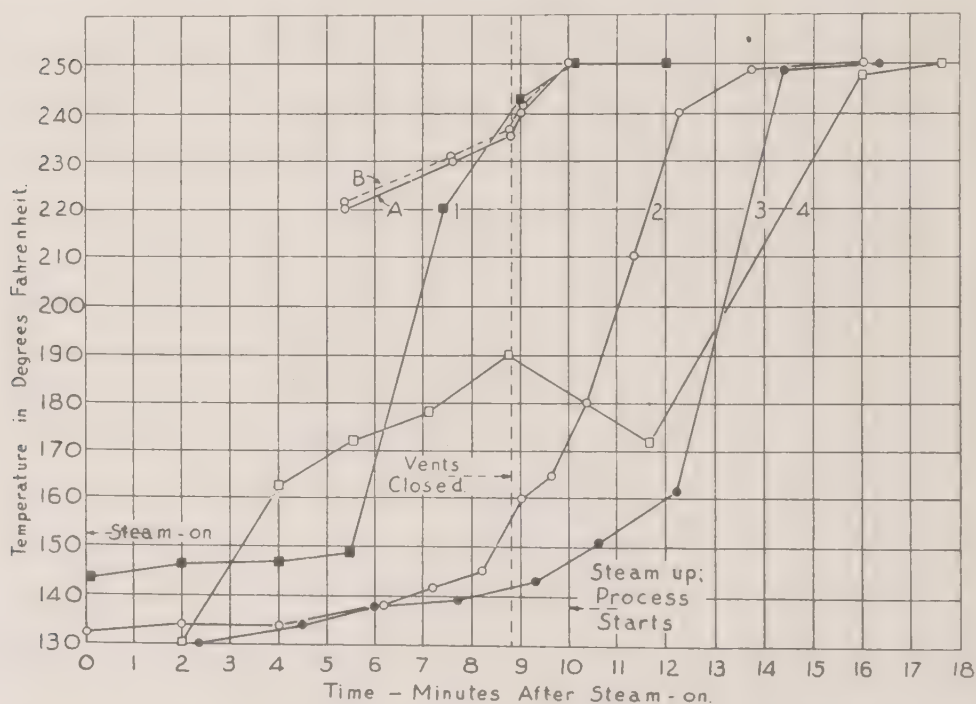
FIG. 94. Graph showing effect of air pockets on temperature-pressure relationship in retort. Points on curves 1, 2, 3 and 4 represent the temperatures at intervals at four different places among the cans in the load. Thermocouple 1 was in a well vented area, while the thermocouples 2, 3 and 4 were located in air pockets. Points on curve "A" represent the temperatures indicated by the mercury thermometer at intervals during the coming-up time and points on curve "B", the temperatures which corresponded with the pressure gauge readings. The timing of the process was started when the mercury thermometer indicated 250°F. as shown by the vertical line drawn at the 10 minute mark on the time scale. At this time the thermometer and pressure gauge readings were in agreement and the discrepancy between the readings of the thermocouples in the air pockets and in the well vented position can be clearly seen.

(Courtesy "Food Industries")

from which it will be seen that when the mercury thermometer registered 250°F. the temperature in an air pocket was only 147°F.

The only way to ensure adequate venting is to adopt a standard operating technique, which by previous experience has been found to be correct, and see that the same procedure is adopted for each batch.

An excellent summary of the best methods of venting horizontal and vertical retorts has been given by Somers[15]. These studies have also produced suggestions for the best type of retort crate to permit the free flow of steam in all directions among the cans.

The stacking of cans in the retort also has a considerable bearing on the amount of air entrapped in the interstices between the cans and Somers[15] has stated that the jumble method of stacking has proved to be the most satisfactory from the heat distribution point of view, but that the retort capacity is reduced by about one-fifth by this irregular arrangement of cans. A further objection is that cans loaded in this manner tend to receive more mechanical damage. The horizontal method of stacking has much to commend it, but it must not be used in certain stratified packs such as asparagus which must be stacked with the longest dimension of the can vertical in order to secure the most rapid heat penetration.

The process may be divided into three distinct sections :—

(1) Raising retort and contents to the processing temperature (Coming-up Time).
(2) Holding at processing temperature.
(3) Cooling.

It is desirable that the coming-up time should be as short as possible compatible with the necessity of removing all the air from the retort. Agreement between temperature and pressure gauges is essential to ensure removal of air from the retort, but as shown above it is not always a reliable indication of the conditions prevailing inside the retort and it is essential that retorts should be tested when loaded under operating conditions to ensure that all air has been eliminated when the pressure and temperature relationship corresponds with the values shown in Table XIV.

When the processing temperature has been reached the retort and its contents are held at this temperature for the necessary length of time. It is important to note that the processing time does not include the coming-up time and the time occupied in cooling, but only the actual time interval during which the retort and its contents are held at the specified temperature.

Automatic controllers are now used which enable the processing temperature to be maintained at a steady value, while cycle controllers

TABLE XIV

Temperature and Pressure of Saturated Steam

Pressure	Temperature	
lbs./in²	F.	C.
0	212.0	100.0
1	215.4	101.9
2	218.5	103.6
3	221.5	105.3
4	224.4	106.9
5	227.1	108.9
6	229.6	109.8
7	232.3	111.3
8	234.7	112.6
9	237.0	113.9
10	239.4	115.2
11	241.5	116.4
12	243.7	117.6
13	245.8	118.8
14	247.8	119.9
15	249.8	121.0
16	251.6	122.0
17	253.4	123.0
18	255.4	124.1
19	257.0	125.0
20	258.8	126.0
21	260.5	126.9
22	262.3	127.9
23	263.7	128.7
24	265.3	129.6
25	266.8	130.3

are also available whereby the whole cycle of operations including coming-up, processing and cooling is automatically controlled and timed. An installation of this type is shown diagrammatically in Fig. 95. The use of a controller of this type, however, tends to decrease the flexibility of the retort and can only be recommended where long runs under the same processing conditions are likely to be encountered. For most purposes a combined recorder and controller will be found sufficient to relieve the operator of the work of maintaining the retort at constant temperature, and at the same time provide a permanent record of the processing conditions of each batch.

After the cans have been held at the processing temperature for the requisite time they must be cooled as rapidly as is consistent with the avoidance of undue strain on the can seams.

During processing the sealed cans develop an internal pressure in excess of the steam pressure in the retort. This excess pressure is produced by the combined effect of the steam generated in the can, the expansion of the contents, and the expansion of the air and other gases which have not been eliminated by the exhaust. Reference has already been made to the work of Magoon and Culpepper[5] in this connection.
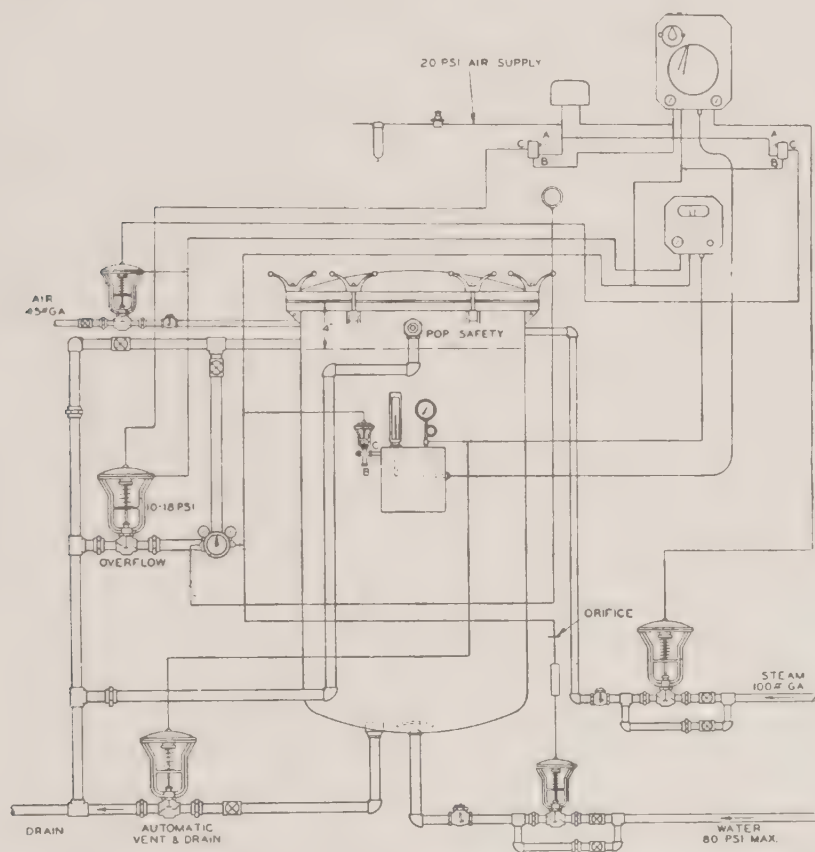
FIG. 95. Cycle controller as fitted to a vertical retort. The whole cycle of operations including coming-up, processing, and cooling is automatically controlled and timed.

(*Courtesy Taylor Instrument Co.*)

The pressure developed is partially balanced by the steam pressure in the retort, but on releasing the steam pressure at the beginning of the cooling period the can ends are subjected to a considerable strain which may result in permanent distortion if the difference in pressure is excessive. The pressure which will just cause permanent distortion has been determined by Adam and Stanworth[16] for a variety of can sizes. When permanent distortion takes place it usually results in sharp bends at one or more points and is known as "peaking." The

pressure differences encountered are well shown in Fig. 96, after Benjamin and Jackson[17].
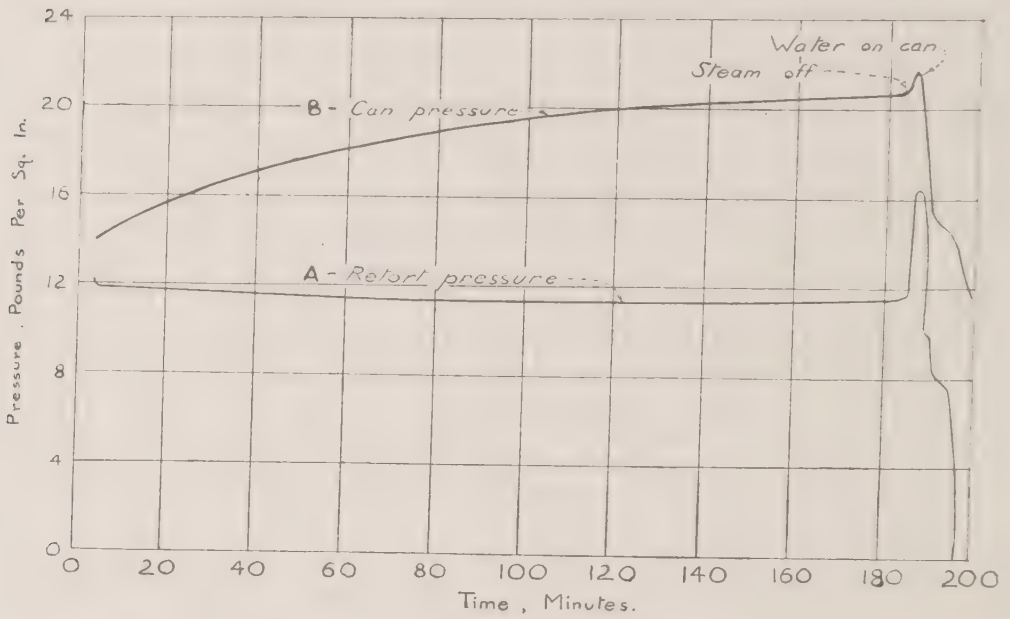
FIG. 96.   Graph showing pressure differences during processing and cooling.
(*Courtesy "Food Industries"*)

The magnitude of the effect of excessive internal pressure varies with the size of can, larger diameters being the more seriously affected. A chart showing the effects on a range of different sized cans has been prepared by the Research Department of the Metal Box Co. Ltd.,[18] and is illustrated in Fig. 97. The lightly shaded portion represents the conditions under which cans closed at 150°F. with 1/4in. headspace will be permanently distorted, although, they will apparently return to normal on cooling and the ends will be concave. The heavily shaded portion represents the conditions under which the cans will show some outward evidence of distortion such as "peaking."

The technique adopted to reduce the strain on the cans during cooling is known as "pressure cooling" and consists of balancing the

FIG. 97.   Diagram illustrating the importance of pressure cooling the larger sizes of cans. For more detailed explanation see text.

(*Courtesy "Food"*)

internal pressure in the can by maintaining pressure in excess of atmospheric in the retort until the cans are partially cooled and the internal pressure has fallen below the danger value. By reference to Fig. 97 it is possible to decide when cans require pressure cooling as all cans for which heavy shading occurs must be pressure cooled, while for cans in the lighter shaded areas pressure cooling is desirable but not essential.

Several different methods of pressure cooling have been reviewed by Benjamin and Jackson[17] who distinquish the following methods :—

> (1) With air and water.
> > (a) Air supplied by compressor.
> > (b) With air injected by steam.
> (2) With steam and water.
> (3) With water only.

The choice of method depends on individual circumstances, but the method most generally used is to use compressed air as this permits the most rapid and uniform cooling. With large horizontal retorts, however, steam injection is sometimes to be preferred by reason of the large volume of air otherwise required.

Retorts fitted for either of the above methods are shown in Figs. 98 and 99, and a full description of the method of operation suggested by Benjamin and Jackson[17] is given below :—

(1) All vents except the indicating petcock on the horizontal retort or the thermometer well petcock on the vertical retort are closed.

(2) Open valve A admitting air into the retort, and close valve S which has admitted steam during the process.

(3) If automatic pressure control is used as in Fig. 99, the controlled pressure should be increased to 3 or 4 lb. above the processing pressure. When the retort pressure has been increased by this amount, open water valve W admitting water into the top of the retort. The water must be admitted slowly at first so as to avoid a sudden drop in pressure due to condensation of the steam. As the steam is gradually replaced by steam the rate of flow may be increased.

With manual air control as in Fig. 98, the pressure will have to be regulated by manipulation of the water valve W and lever valve A. In the case of automatic pressure control as in Fig. 99, only the water valve W will require manipulation.

(4) As soon as pressure can be maintained without further air the air control valve A is closed.

(5) As the retort continues to fill with water the pressure will gradually increase and the top valve controlled vent or the air
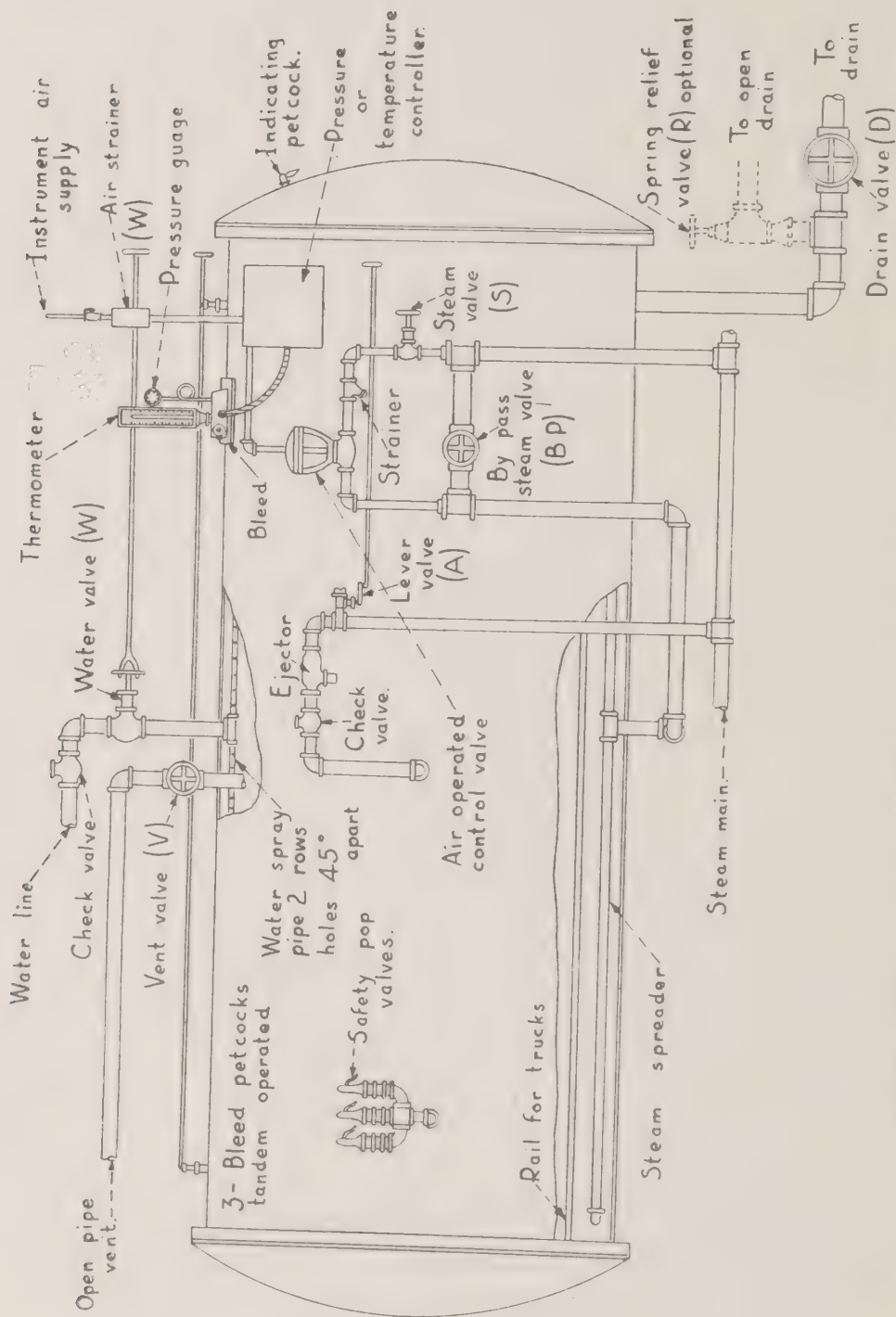
14

Fig. 98. Horizontal retort equipped for pressure cooling by steam injected air.
(Courtesy "Food Industries")

relief valve **AR** should be opened to regulate the pressure to the desired value. As the water level approaches the top of the retort as indicated by the petcock the flow rate of the water should be reduced so that the pressure can be more accurately controlled when the retort is filled.

(6) When the retort is full the pressure will rise suddenly and the drain valve **D** should be opened and adjusted to regulate the pressure to the correct value. The vent valve **V** or air relief valve **AR** should, of course, be closed. If a spring relief valve **R** is used, it will simplify the pressure control at this stage.

(7) The pressure may be regulated by manipulation of the water valve **W** and the drain valve **D**. The pressure cooling operation is completed by reducing the pressure at a predetermined rate depending on the type of product being cooled.
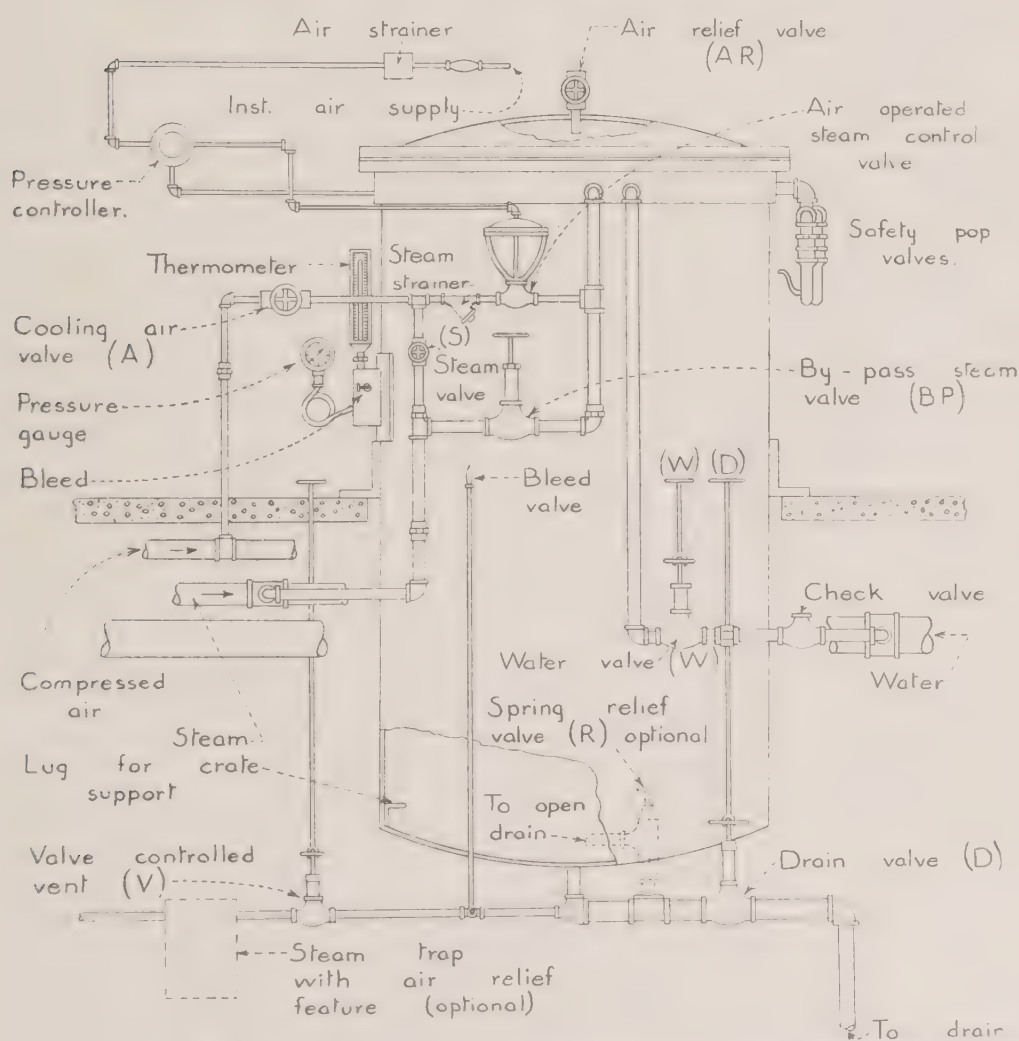
FIG. 99. Vertical retort equipped for pressure cooling by compressed air.
(*Courtesy "Food Industries"*)

The error most frequently made in pressure cooling is to admit the cooling water too quickly causing a loss of pressure and thereby vitiating the entire operation.

Cooling should be continued until the temperature of the cans is reduced to about 100°F. at which temperature there is sufficient heat still left in the cans to dry them and avoid rusting. Baumgartner[10] points out that cooling in water should not be continued until the cans are quite cold, otherwise, the vacuum so formed will be an additional factor to be added to the external pressure which tends to cause water to penetrate the seams with the possibility of initiating bacteriological spoilage due to contamination of the can contents by micro-organisms in the cooling water. It is, therefore, most important to ensure that only water of a low bacterial content is used for pressure cooling.

Since the introduction of the retort for processing canned foods much progress has been made in its design and construction and Ball[19] has rightly stated that the four steps which stand out for their importance in the advancement of the technique of "still" retort operation are :—

(1) The introduction of the indicating pressure gauge and the indicating thermometer as standard retort equipment.

(2) The change from the generation of steam in the retort to the piping of externally generated steam into the retort.

(3) The studies of heat penetration through the container and of the temperature distribution within the retort, especially studies made with thermocouples.

(4) The introduction of automatic temperature and pressure recorders.

Reference has already been made to the use of automatic temperature and pressure controllers and recorders and no retort should be without these instruments which not only relieve the operator of the necessity of controlling the process, but also reduce steam consumption and ensure uniform processing conditions. An excellent outline of the application of automatic control to all types of processing has been given by Schmid[8] and further details may be obtained from the respective instrument makers who now offer a very wide range of instruments suitable for the control of all kinds of heating processes used in food canning.

Reference has already been made to the recommendations made in the bulletin of the National Canner's Association[14] regarding the equipment of a retort and this bulletin also specifies processes for a wide range of non-acid canned foods. The importance of coding the cans

before processing and the desirability of reducing the holding period between closing and processing are among other points also emphasised.

Batch Type Retorts (Agitating). This type of retort is mainly used for the processing of milk, but it is also used for thick soups and similar products which are not damaged by agitation and which show an increased rate of heat penetration if agitation is employed and thereby permit a shorter process at a higher temperature.

Unless a retort of this type is used for processing milk there is a tendency for caramelisation of the can contents to occur.

Retorts of this type are usually horizontal cylinders, the cans being placed in trays which are then placed in a cage which is run into the retort, the door closed and the driving mechanism connected up to the cage which revolves inside the retort.

A retort of this type which combines a rotary and a shaking motion has been developed and as shown in Fig. 100 two such retorts are sometimes placed end to end and utilise a common driving mechanism.

Fig. 100.   Retorts equipped for rotating and shaking during processing.   Two retorts are placed end to end and utilise a common drive.
(*Courtesy Berlin Chapman Co.*)

Continuous Pressure Cookers (Still). The use of a continuous cooker offers many advantages. In the first place there is a considerable economy in steam, air, and cooling water as once the desired temperatures are reached they are maintained throughout the length of the run. In addition the control of the process is more accurate, as each can is passed directly into the cooker from the seaming machine and no time lag is incurred as is of necessity the case when loading a discontinuous retort.   Furthermore, the can encounters the full processing temperature immediately it enters the cooker thus ensuring that every can during the run receives the same heat treatment.

Continuous cookers are well adapted to automatic control of temperature as with a continuous throughput of cans all that is

required is a smoothing of the minor variations which occur due to fluctuations in steam pressure and external temperature, etc.

The type of continuous pressure cooker illustrated in Fig. 101 is much used where agitation of the cans is not required, the cans being conveyed in a vertical position on special chain. The unit construction of this particular cooker makes it adaptable for a wide range of products with widely varying processing times.
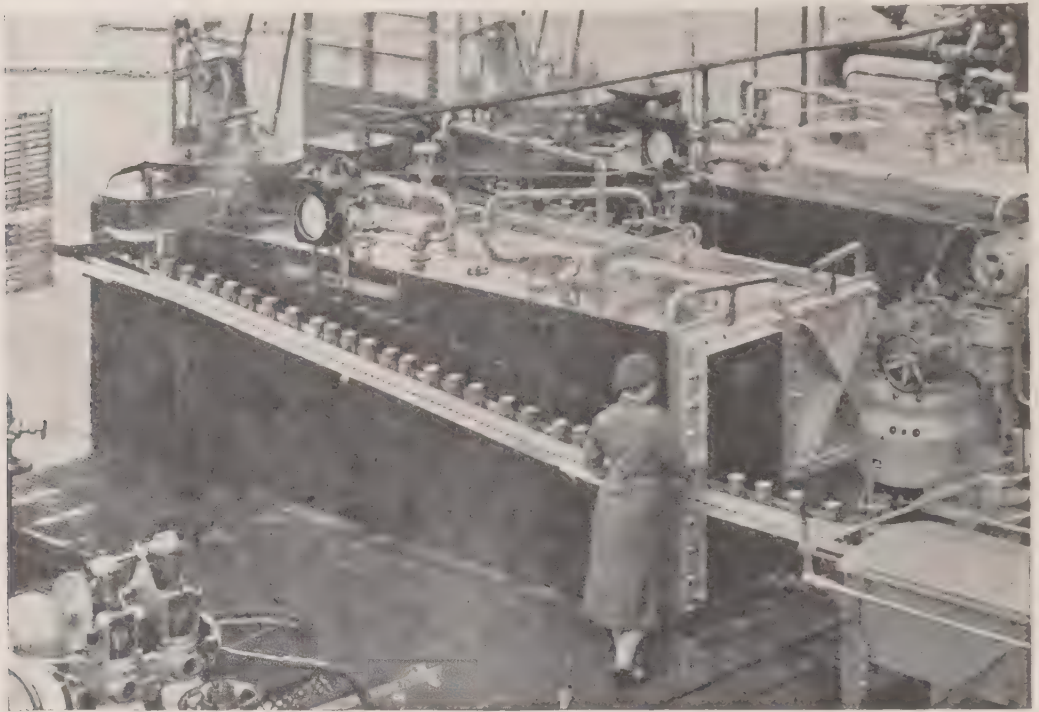

FIG. 101. Continuous pressure cooker in which the cans are conveyed in a vertical position without agitation.

(Courtesy Mather and Platt Ltd.)

Continuous cookers, however, have a disadvantage in their lack of flexibility as compared with the batch type retort and they can only be worked economically where long runs on the same product are made.

Continuous Pressure Cookers (Agitating). Cookers of this type offer all the advantages of the non-agitating type described above, and in addition the agitation given the cans during processing increases the rate of heat penetration and enables higher temperatures and shorter times to be used with certain products. The continuous pressure cooker is a logical development of the open agitating cooker, the chief difficulty in construction being the transfer valves which feed the cans into the cooker, transfer the processed cans to the cooler and

finally discharge the cooled cans. All these operations must be carried out without loss of steam between cooker and cooler or to the atmosphere.

There are several different types of agitating continuous pressure cookers, a typical example is shown in Fig. 102 which shows a cooker adapted for processing canned milk and includes a forewarming unit in which the cans are gradually brought up to the processing temperature before going into the cooker proper. With other products the forewarming unit is omitted.
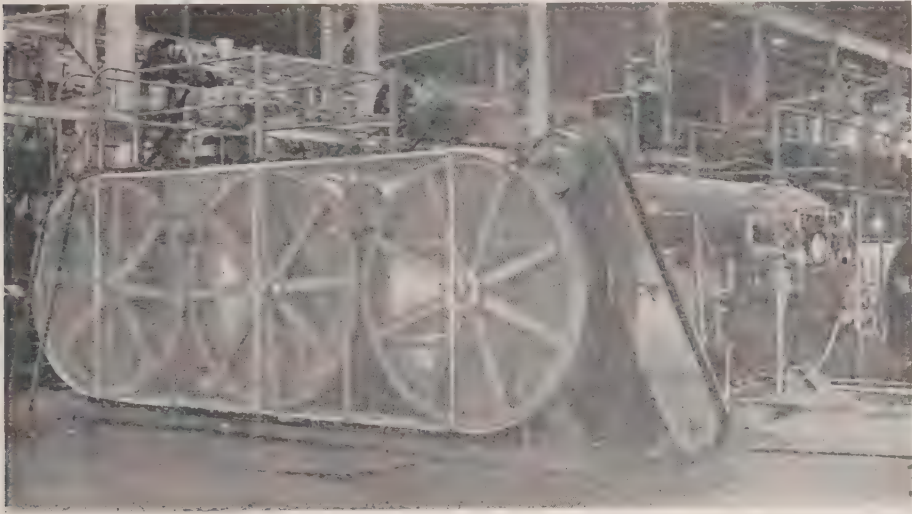
FIG. 102. Continuous pressure cooker and cooler for milk processing.
(*Courtesy Mather and Platt Ltd.*)

In Fig. 103 in addition to the pressure cooker and cooler an atmospheric cooler is included for those products which are processed at high temperatures and cannot be fully cooled under pressure. The
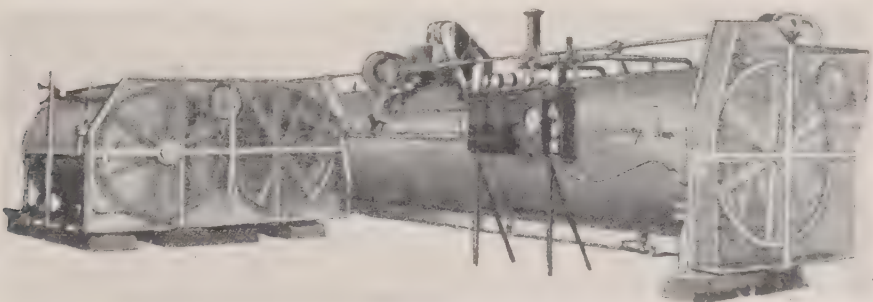
FIG. 103. Continuous pressure cooker and cooler with atmospheric cooler.
(*Courtesy Food Machinery Corporation*)

pressure cooler brings the internal temperature of the can down to a point where it can safely be ejected into atmospheric pressure, the cooling operation is then completed in the atmospheric cooler.

As in the case of the non-agitating pressure cookers the agitating types are also well adapted for the automatic control of temperature, and when properly handled are capable of producing very high quality products to a uniform standard.

Regardless of the system of processing adopted, the essential requirements may be summarised as follows :—

(1) Delay between closing and processing must be reduced to a minimum.

(2) Each can must be subjected to the same thermal treatment by ensuring even temperature distribution in the processing equipment and accurate control of the temperature and duration of the process.

(3) Where batch type equipment is in use it is particularly important to ensure that there is no variation in thermal treatment between batches.

Cooling after Processing.   The rapid cooling of cans after processing is an important factor in determining the final quality of the finished product. Insufficient or too slow a rate of cooling may affect the quality of the pack in one or more of the following ways :—

(1) Deterioration of the colour and/or flavour.
(2) Breakdown in texture.
(3) Growth of thermophilic organisms is encouraged.
(4) Reactions leading to corrosion are accelerated.

It will be seen, therefore, that efficient cooling can contribute a great deal to the quality of the finished pack and also play a part in the prevention of "flat sours," hydrogen swells, and excessive corrosion of the can.

In an investigation of the cooling of cans Kohman and Sanborn[20] pointed out that the efficiency of any cooling system may be estimated by measuring the temperature of the inflowing water, the temperature of the out-flowing water, and the time of cooling. The same authors also state that the ideal to be attained in cooling is to reduce the temperature of the cans to such an extent that they retain only just sufficient heat to dry off the surface moisture and thus prevent external rusting. This will be achieved if the temperature is reduced to about 100 F., the exact temperature depending on the external atmospheric conditions.

As already described under continuous processing methods the continuous cooler is usually coupled directly to the cooker. With batch type processes the cooler may consist of a long tank of cooling water through which the processed cans are conveyed in retort baskets by means of an overhead conveyor or by a continuous belt. An alternative method is to pass the cans under sprays of water.

A new type of cooler developed for cooling fruit juices allows the cans to spin thereby picking up a thin film of water and at the same time agitating the contents, thus securing an extremely rapid transfer of heat.

The possibility of water borne micro-organisms contaminating the can contents during cooling has occupied the attention of many workers during the last few years and Bashford[21] states that it is now generally recognised that cooling water should not contain more than about 50 viable organisms per millilitre if spoilage is to be avoided. In a comprehensive study of chlorination Harris[22] points out that cooling tanks and continuous coolers may be subject to a considerable build up of bacteria unless adequate precautions, such as continuous chlorination, are taken.

During cooling the pressure inside the can gradually drops until a vacuum is eventually formed and it is at this stage that the can is an optimum condition to permit the ingress of any spoilage organisms which may be present in the cooling water.

The importance of avoiding rough handling of the cans has been stressed by Smith[22], and by Blackwood and Kalber[23] who showed that when careless handling is combined with contaminated cooling water spoilage may reach a very high value. The methods available for the chlorination of cooling water are discussed in Chapter 5, but it is of interest to note here that Bashford[21] suggests a residual chlorine content of 1 to 2 p.p.m. when the contact time is 20 to 30 minutes, but it is essential that each case should be judged on its merits rather than to fix any general limit for residual chlorine.

A word of warning must be given in connection with the application of chlorine to cooling water as, although, when applied under careful supervision the procedure has much to recommend it, the first essential is to ascertain that the can seams are up to standard, otherwise, there is considerable danger of cans which would normally become infected in contaminated water and thus be eliminated in the cannery, being passed as sound when chlorinated water is used only to become infected at some later date.

The essentials of cooling may be summarised as follows :—

(1) Cool as rapidly as possible without undue strain on the end seams.

(2) Leave sufficient heat in the cans to dry off the surface moisture and avoid rusting.

(3) Where contaminated water must be used, chlorinate after ensuring seams are sound.

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CHAPTER 9

MISCELLANEOUS OPERATIONS

In addition to the main operations in the canning process which have been described in previous Chapters there are a number of subsidiary operations which all play an important part in the production of the finished pack. These operations which are carried out at various stages in the canning process have been grouped together in the present Chapter.

Coding of Cans

The positive identification of a can is often necessary, when for any reason the canner wishes to check back on his output, and coding provides a means of doing this.

The codes in use consist of a series of letters or numerals, as shown in Fig. 104, stamped or printed on the canners end. The simpler codes only distinguish the product and the date packed, but the more complicated forms may identify the actual batch.

Fig. 104. Two methods of coding can ends, embossed code (left), and printed code (right).

During the recent war when the risk of labels being destroyed by fire or water was high, all canners in the United Kingdom used a uniform code to designate the can contents, but under normal conditions each canner uses his own particular code.

With an embossed code the embossing operation may be carried out in conjunction with the lid feed on the seaming machine, or it may be carried out on a separate machine devised for the purpose.

The printed code is usually applied by means of a rubber stamp using an ink specially formulated to withstand processing.

An electrolytic method of coding has been developed and patented by Clayton and Sumner[2], the electrolytic process being so chosen that the surface of the container is altered in such a way as to render the desired marking clearly visible in contrast with the untreated portion of the surface.

One disadvantage of the embossed code is that if the embossing is too deep the tin coating may be fractured, thus increasing the possibility of corrosion of the steel base. This is particularly serious in the case of lacquered or plain cans used for acid products. The effect of heavy embossing has been demonstrated by Cheftel[1] who used the ferricyanide test referred to in Chapter 2 to show the extent of exposure of the steel base.

The printed code and electrolytic code do not damage the tin coating and are, therefore, to be preferred, but care must be taken in the case of the printed code to see that there is no possibility of the ink contaminating the can contents. Cases have been reported, for example, in which lids were stacked in the end feed of the closing machine immediately after coding and the wet ink contaminated the inner surface of the can end immediately above it, and an off-flavour developed in the can contents

Whichever method of coding is adopted it must be permanent and easily legible. With an embossed code the number of letters or figures should be kept to a minimum to reduce the risk of fracturing the tin coating.

Can Washing

In many packs particularly meat and vegetable mixtures, sausages, soups, etc., the cleaning of the cans is no easy task. It is important that the exterior of the cans should be bright and clean, otherwise the can will present an unattractive appearance to the consumer, and, furthermore, the presence of particles of food and other materials on the outside of the can may encourage corrosion.

The washing of cans containing fruit or vegetables does not present much difficulty as traces of syrup or of brine are usually easily removed. Meat and fish packs, however, present a much more difficult problem and special care is required if washing is to be successfully carried out.

Ideally, washing should be carried out both before and after processing, but in actual practice it is usually sufficient if a thorough

cleansing is given just before processing. Washing at this stage avoids any baking on of the food particles such as may occur when washing is deferred until after processing. A further advantage is that contamination of the retort or cooker is avoided.

Can washers may be obtained in many different types, there is, for example, the relatively simple, but nevertheless effective model shown in Fig. 105 consisting of a rotating wheel carrying a number of brushes which pass through a bath of heated detergent solution as the wheel revolves. Additional brushes are also provided for cleaning the ends of the cans as they pass through the washer. The speed of the delivery pulley is one-third that of the receiving pulley so that the cans remain in contact with the brushes for sufficient time to permit a thorough cleaning to take place. This type of machine cleans about 80 cans per minute.

The inclusion of some form of brushing during the washing process does appear to give the best results with heavily contaminated cans, but a subsequent water spray is also desirable to remove any loosened particles.

FIG. 105. Can washer incorporating a number of rotating brushes.
(*Courtesy Robert Kellie and Son Ltd.*)

In one highly mechanised type of spray washer the machine is divided into three compartments consisting of a wash and a drain, a rinse and a drain, and finally a drying section which dries the washed and rinsed cans by means of a heated air blast. This last operation may be omitted if the cans are washed immediately before processing. A machine of this type uses about 300 gallons of water per minute at about 40 lbs./in.^{2} pressure and will wash 7,200 cans per hour. In most washers mild alkalies are added to the washing water to facilitate the cleaning of the cans. Improved results are obtained, however, by using one or other of the synthetic detergents now available.

It is important that the detergent solution should not attack the tinplate, otherwise the tin coating may be partially dissolved and the

so-called "feathering" or etching of the tin coating will be observed. This etching action indicates that the washing solution is too drastic in action and must be diluted or its constituents changed. The can washing process is a convenient stage at which to carry out any chemical treatment of the exterior of the can to increase the corrosion resistance of the tinplate. The normal washing solution may, for instance, be replaced by the solution developed by Kerr[3] to which reference is made in Chapter 3. In this case it is desirable to arrange for the recirculation of the solution otherwise loss of solution may render the process uneconomic.

In carrying out any chemical treatment care must be taken in the choice of materials used in the construction of the washer, some materials when in contact with tinplate in the presence of the treatment solution promote severe corrosion of the can by electro-chemical action and must, therefore, be avoided.

External Lacquering

Cans for export to tropical climates or which may be stored under excessively humid conditions are usually protected from rusting by the application of a coating of lacquer to their exterior surfaces. The simplest type of lacquer used for this purpose consists of shellac dissolved in a suitable solvent such as industrial alcohol. The lacquer is applied by rolling the cans to be lacquered through a bath of the lacquer solution, the coated cans being dried by rolling down a runway of such a length that the cans are dry by the time they reach the end. In some cases drying is accelerated by lacquering the cans while they still retain some heat from processing, or alternatively a counter current of heated air blowing up the runway may be used.

The practice of allowing the cans to roll down a runway for drying results in most of the lacquer being removed from the end seams, and this part of the can does not, therefore, receive any protective coating. A further disadvantage is that the shellac type lacquer is somewhat brittle and tends to flake off if the cans are roughly treated.

During the recent war when it became necessary to send canned foods to all parts of the world, often into extremes of temperature and humidity, improved lacquering methods and types of lacquer were developed to overcome the defects of the shellac type of lacquer referred to above. These new lacquers contained various synthetic resins which produced a hard yet flexible coating.

The new lacquers necessitated a revision of the method of application as they dried at a much slower rate than the normal shellac type of lacquer, and furthermore, as it was desired to obtain the maximum corrosion resistance, the practice of allowing the cans

to roll down an inclined runway had to be discontinued to avoid removing the lacquer from the end seams.

Several new devices were developed to meet the conditions imposed by the new lacquers. In one such device, which gave very satisfactory results, the cans were suspended by a spring clip which gripped the can in such a manner that marring of the lacquer surface was reduced to a minimum and at the same time the can was held at the optimum angle to secure rapid draining of the surplus lacquer. The suspended cans were carried through a bath of lacquer, which was agitated to prevent settling, and then through a heated drying chamber the temperature and rate of travel being so adjusted that the cans were sufficiently dry to handle by the time they returned to their starting point.

An air drying lacquer of the type mentioned above does not have the same resistance to abrasion as a lacquer coating applied before fabrication and stoved at a fairly high temperature. If, therefore, the greatest possible resistance is required a stoved lacquer should be used. In this case it is usually necessary to lacquer the side seam of the can by spraying or brushing as it must be left bare of lacquer until after fabrication in order to permit soldering in the body maker.

Incubation

The incubation of representative samples of finished cans is referred to in the section dealing with the examination of the finished pack. This procedure is adopted to encourage the development of any viable organisms present in the cans so that they may be cultured and identified.

A similar procedure may be adopted with the entire production of certain packs such as meat packs and other packs which will not be affected by storage at elevated temperatures. It is not advisable, however, to incubate fruit and vegetable packs as the formation of hydrogen swells and other corrosion phenomena are accelerated by any increase in temperature.

Mass incubation is usually carried out in specially constructed rooms in which the temperature is thermostatically controlled. The provision of recording thermometers is a refinement which enables a continuous record of the incubating conditions to be obtained, a record which may be of considerable value should any spoilage develop at some subsequent date.

The cans are commonly incubated at 37°C., or if the development of thermophiles is likely to occur at 55°C.

Incubation will, of course, only detect spoilage by gas producing

organisms, "flat sours" will not be shown up and reliance must be placed on laboratory examination of representative samples for the recognition of this type of spoilage organism.

The value of incubation in detecting the possibility of spoilage and making possible the removal of defective cans is well shown in the example cited by Bashford[4] in Table XV. These results relate to a pack of meat and vegetables which it was decided to discontinue due to heavy spoilage. The spoilage was caused by facultative thermophilic anaerobes and the high fat content of the pack appeared to have a protective action on the spoilage organisms, which were not destroyed by what would normally be regarded as an adequate processing time and temperature.

TABLE XV

Results of the Incubation of a Number of Meat and Vegetable Packs
(*Bashford*)

Product	No. of cans incubated	No. of cans blown	No. of cans blown per 10,000 incubated	Approx. fat content of pack
				%
Irish stew	666,401	626	9.39	8–8.5
Minced meat and vegetables	2,866,667	1414	4.93	4.5
Pork and vegetables	90,213	176	19.51	9
Meat and vegetables	560,387	333	5.94	2.3

Incubation provides the canner with a means of eliminating a high proportion of any defective cans. In a well run cannery the percentage of defective cans should be very small, but it is well worth the additional expenditure incurred by incubation if these few defectives are eliminated, as nothing is more damaging to the canner's reputation than a few unsound cans reaching the retail market.

Labelling

The importance of careful labelling and the choice of a bright and attractive design cannot be over-estimated, as besides indicating to the consumer the contents of the can, a well-chosen label is often an important selling feature for a new product. Needless to say, the contents of the can must support the description on the label, otherwise the value of the label as a selling feature is likely to be very short-lived!

Recent legislation in the United Kingdom has made it obligatory for the canner to indicate on the label the quantity or proportion of each ingredient used in the pack, or, alternatively, the ingredients must be specified in the order of the proportion in which they are used, the ingredient used in the greatest proportion (by weight) being specified first, followed by the next greatest, etc. It is also obligatory for the net weight of the can contents and the canner's name and address to be clearly stated on the label. The inclusion of a list of the ingredients on the label is a very sound provision as it safeguards the public against the purchase of an inferior article.

A further section of the Order of especial interest to pea canners is that which makes it obligatory for "processed" peas to be described as such, thus avoiding the confusion with canned fresh peas which sometimes occurred.

In addition to carrying information on the ingredients, the canner's name and address, etc., it is customary, particularly in the U.S.A., to include recipes illustrating methods of utilising the can contents. This practice has a great deal to recommend it as a means of encouraging the increased use of canned foods.

At the present time restriction of paper supplies prevents the greater use of labels covering the whole body of the can, but under normal conditions it is the common practice to apply labels covering the entire body of the can between the end seams.

The actual application of the label to the can is frequently given too little attention. A label which is not straight, or which overlaps the can, spoils the whole effect no matter how good the design.

Round open-top cans are usually labelled by automatic labelling machines which may label up to about three hundred cans per minute, depending on the size of the can. In one form of labelling machine the cans roll into the labelling machine by gravity and are then picked up by two motor-driven endless rubber belts, which press on the end seams and pass the cans through the labelling machine. The cans pass over a gum or glue pot, which applies a trace of adhesive to the can body by means of a moving chain or a number of rotating discs. The gum or glue pot is often heated and thermostatically controlled to maintain constant temperature. The cans then continue rolling through the machine until they reach the label table, on which the labels are placed face down. The trace of adhesive previously applied to the can body picks up a label, which then wraps itself round the revolving can. Paste is applied to the lap of the label, which then adheres to the end already in contact with the can, thus encircling the can body. The label box or table is equipped with a device which automatically raises the stack of labels as they are removed.

Unless mass incubation is to be carried out, labelling may take

place immediately after cooling, provided the cans are sufficiently dry. If, however, the cans are to be stacked before casing it is advisable to defer labelling until the cans are to be cased, otherwise the labels may be damaged during storage.

The correct choice of label adhesive is important, as it must not only fix the label securely to the can, but it must also be free from any substances which are likely to promote corrosion, and excessive acidity or alkalinity must, therefore, be avoided.

Examination of the Finished Pack

Laboratory examination of the finished pack represents the last link in the chain of controls which commenced with the examination of raw materials and which was designed to ensure the production of a high quality and uniformly "commercially" sterile pack.

The examination may be conveniently divided into two groups :—

1. Bacteriological examination.
2. Physical and chemical examination.

Bacteriological examination of the finished pack is carried out in order to test the efficacy of the heat processing and also to determine whether any viable organisms remaining in the can are likely to produce spoilage or shorten the shelf life of the product.

An important factor in bacteriological examinations of this type is to ensure that the samples examined are representative of the condition of the whole pack. In the examination of canned fish Jarvis[5] recommends that twelve cans from each batch should be regarded as the minimum, while twenty-four cans are to be preferred. The actual number of samples taken, must, however, be governed by the size of the batch upon which information is required. In some cases additional samples will be required for the physical and chemical examination.

It is common practice to incubate sample cans taken for bacteriological examination in order to encourage the growth of any surviving organisms, but as Esty and Stevenson[6] point out, some organisms may remain dormant unless incubation is continued for very long periods, often outside practical limits.

A minimun incubation period of one week at 37°C. is suggested by Baumgartner[7] for low and medium acid products, and a few days at 55°C., while Esty and Stevenson[6] recommend four to seven days at this temperature. For acid products ten days' incubation at 25°C. is regarded as adequate by Baumgartner[7].

It is essential that a daily examination of the cans undergoing incubation should be made and any showing signs of spoilage should be

removed immediately for culturing, etc., and a note made of the period of incubation.

The technique of the bacteriological examination of canned foods has been described by Esty and Stevenson[6], Tanner[8], and, most recently, by Baumgartner[7], who outlines a suitable technique for the routine examination of canned foods such as may be carried out in the cannery.

In interpreting the results of an examination of this type it is important that the data obtained should be correlated with that derived from the physical and chemical examination, otherwise erroneous conclusions may be drawn. The results of the bacteriological examination should provide information on the following :—

(1) The possibility of spoilage occurring within the normal shelf life of the product.

(2) If viable organisms are found, whether they are of a type liable to have survived processing and whether they are present in sufficient numbers to indicate insufficient processing, or an abnormally heavy initial contamination.

(3) If non-heat resistant organisms are found, whether they have entered the can after processing and are viable or whether they were present in the can before processing, and were destroyed by the sterilising process.

The physical and chemical examination will provide information on the quality of the finished pack and also on the efficiency of the canning technique, but in addition tasting panels play an important part in the examination of canned foods, as indicated in Chapter 11 and the examination of the finished pack by a panel of impartial and trained observers is a very useful method of checking up on the quality of the cannery output, and also provides useful information on the acceptability of new packs and products.

At the present time there are no statutory standards in force in the United Kingdom concerned solely with the quality control of canned foods, and it would appear that the time is particularly opportune for the introduction of a series of standards for the more popular canned foods on similar lines to those adopted in the U.S.A., Canada, and elsewhere.

The National Mark scheme, which was introduced in 1930, was a step in the right direction, and the work of Hirst[9] and his associates at the Fruit and Vegetable Preservation Research Station in examining samples submitted under the National Mark scheme was of great value, but the recent war has resulted in the scheme being allowed to fall into abeyance.

These examinations covered colour, texture, size-grading, blemishes and defects, flavour, drained weight, total weight, density of syrup, and condition of can. They, therefore, enabled an accurate assessment of the quality of a particular product to be made, and attainment of a high standard in all the above factors was required before a product could be included in the top grade of the scheme.

As already stated, there is at present no scheme to replace the National Mark in operation in the United Kingdom, but a voluntary scheme is, however, reported by Adam[10], who states that the vast majority of the fruit and vegetable canners in the United Kingdom have co-operated to make the scheme a success.

Assessment of quality is based on a points system, in which such factors as colour, texture, absence of defects, size-grading, and flavour are allotted points, a certain minimum value being assigned to each grade.

During the first seven months of the scheme over five thousand cans were examined on this basis.

The scheme referred to above only covers fruit and vegetable products, but the regular examination of all other canned foods is just as essential.

There is little doubt that the regular examination of finished goods by an impartial and highly critical panel can do a great deal to improve and maintain quality.

It is suggested that all canners might well adopt a regular inspection scheme of their own products, as by so doing they will be ensuring that quality is maintained and any defects in canning technique will be rapidly revealed, thus enabling appropriate measures to be taken to eliminate the cause of the trouble.

The physical and chemical examination should provide information on the following points :—

(1) External appearance of the pack.
(2) Mechanical soundness of the can.
(3) Presence of any deleterious substances such as salts of metals, etc.

The examination of the external appearance of the pack is usually made the first stage in the laboratory examination.

Careful note should be made of the condition of the ends, body, and of any sign of denting or rough handling, or other obvious defects. The condition of the label, if present, should also be noted, with particular reference to the presence of rust spots.

A review of the relation of the external appearance of cans to the soundness of their contents has been given by Hallman[11] who points

out that cans with the same or similar external appearance do not always contain products which are in the same condition, and that it is usually necessary to confirm conclusions reached from the external appearance by actual examination of the contents.

The mechanical soundness of the can is largely a function of the effectiveness of the end and side seams in forming an hermetic seal. Methods for the dissection of the end seams and the measurement of their component parts have already been given in Chapter 8, and it need only be said here that the methods adopted by the can fabricator to check his output apply with equal force to the examination of the closed can in the cannery.

The chemical analysis of canned foods will show the presence of any deleterious substances such as metallic salts, and when considered in conjunction with a similar analysis of the raw materials before canning serves as a useful means of detecting any contamination occurring in the plant.

The foregoing paragraphs have been devoted to the routine examination of sound canned foods such as will form the vast majority of the canners' output; nevertheless, in spite of all precautions, some degree of spoilage must be expected and the examination of spoiled canned goods often affords a valuable means of determining the cause of the trouble. Examination of spoiled canned food calls for far more exhaustive procedure than that adopted for the routine inspection of day to day production, it is particularly important in the case of bacteriological spoilage, for example, to identify the type of organism causing the trouble.

A very useful contribution to the literature on methods of determining the cause of a spoilage outbreak, in this case hydrogen swells, has been made by Adam and Dickinson[12]. In their investigations the following factors were studied :—

Can.	*Contents.*
External appearance.	Headspace.
Internal appearance.	Original vacuum.
Thickness of tin coating.	Gas analysis.
Corrodibility of steel base.	pH and acidity.
Appearance of corroded strips.	Tin and iron content.
Analysis of steel base.	Corrosivity index.

The determination of the cause of hydrogen swells very often presents a most complex problem and many of the above factors may have to be investigated before the source of the trouble can be definitely located.

In many cases of spoilage, however, the cause is more easily determined, but the above serves as an excellent example of what may be required in certain cases.

In setting up any system for the examination of the finished product it must be borne in mind that for the results to be of any value they must be available before the finished goods leave the factory, and an excellent system is to make the laboratory responsible for giving a clearance based on its examination before any finished goods are permitted to leave the cannery, this, of course, implies that the results of the examination will be made available in a reasonably short time if delivery of the finished goods is not to be held up.

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CHAPTER 10

METALS AND CANNED FOODS

THE rapid increase in the consumption of canned foods during the past decade has focused attention on the possibility of significant quantities of metal, particularly tin, being dissolved by the contents of the can and subsequently absorbed into the system of the consumer by way of the digestive tract. In addition to purely pharmacological considerations it has also been shown that "off flavours," rancidity and discoloration may result from the presence of excessive quantities of certain metals in canned foods.

Most foods have a natural metal content which must be taken into account when deciding the maximum permissible limits for the metal content of a particular food.

Morgan and Rawlings[1] summarised the factors affecting the toxicity of a particular metal as follows :—

(1) The form in which the metal is present in the food, i.e., whether it can be absorbed through the digestive tract.
(2) The irritant properties of the metal.
(3) The quantity of the metal ingested.
(4) Whether the metal is cumulative.
(5) Certain specific reactions of the metal.

The chief metals which may be found in canned foods are arsenic, copper, lead, tin, zinc, and with the increased use of aluminium, this metal may also be found in significant quantities.

Metals in canned foods may be derived from the following sources :—

(1) The plant or equipment in which the food is prepared or handled before canning.
(2) The natural metal content of the food.
(3) Substances which have been added to the food for special purposes.
(4) The products derived from the corrosion of the can by its contents.

Tin

References to the tin content of canned foods can be traced back to the time when the canning industry was in its infancy ; much of

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the early work on the effect of tin on the human organism was carried out by observing the results of the intravenous injection of tin salts. With food, however, a very different state of affairs exists, as any tin entering the system must do so through the digestive tract, it is unlikely, therefore, that any reliable conclusions can be drawn as to the effect of tin salts in canned foods on the human body from the results of experiments involving the direct injection of tin salts into the blood stream.

Tin is normally present in animal tissue and the human organism. Bertrand and Ciurea[2], for example, have found 0.5 - 4.0 p.p.m. in fresh beef, horse, and mutton, with larger quantities up to 12 - 26 p.p.m. in the tongues of these animals. In the human organism Misk[3] found 5.9 p.p.m. in the brain and up to 137 p.p.m. in the liver, where the highest concentration is usually found. Tin salts have also been shown to be present in milk and fish.

Cases of poisoning alleged to have been caused by tin salts have been reported from time to time, but in the majority of cases it has not been conclusively proved that tin salts have been responsible for the trouble. Luff and Metcalfe[4] reported four cases of poisoning caused by canned cherries, in which the cherries were found to contain approximately 3,500 p.p.m. of tin, a figure far in excess of any that is likely to be obtained with the modern open-top can. Numerous other cases have been reported, but, as in the above example, the type of can has been mostly of the fully-soldered variety, a type now little used except for such packs as corned meat and milk, where attack of the can by its contents is rare.

The toxicity of tin salts has been examined by many workers, among them Schryver[5], Salant, Rieger and Treuthardt[6], and Pedley[7]. Feeding tests were carried out on animals, the general conclusion being that tin even when administered in large doses by mouth, is not absorbed in large quantities through the digestive tract, and, in any event, is readily eliminated. Schryver[5] conducted feeding experiments on himself and demonstrated that even with amounts of tin far in excess of those likely to be encountered, at that time, in canned foods, no ill effects were felt. The first comprehensive survey of the tin content of canned foods was made by Buchanan and Schryver[8] over thirty years ago. As a result of their work they came to the conclusion that amounts of tin in excess of two grains per pound (286 p.p.m.) justified the view that the food was potentially deleterious to health. This view, which was based on the tin content of canned foods packed in a type of container no longer in general use, took no account of the possibility of a proportion of the total tin content being in such a form as to be unabsorbed by the digestive tract.

A paper by Bigelow[9] showed that there was an uneven distribution of tin between the solid and liquid portions of the pack. His results in Tables XVI and XVII also show that the amount of tin in the solid portion of the pack increases with time. A most important paper on this subject is by Goss[10], who showed that there was a relation between the protein content of the food and the amount of tin in the insoluble form. It was found that in such products as rhubarb and beets, which are low in protein, a high percentage of their total tin content is in the soluble state, while in foods high in protein a large proportion of the tin is in the insoluble state. Tin was also found concentrated in the seeds of such fruits as raspberries and strawberries, the latter containing 2.630 p.p.m. in the seeds compared with 416 p.p.m. in the whole fruit. In another paper[11] the same author showed that tin is readily absorbed from solutions of its salts by coagulated proteins. The absorption complex is very stable and does not lose tin to a dilute acid or alkaline phase which is tin-free. Artificial tryptic and gastric digestions showed that in the case of proteins containing amounts of tin comparable with that found in canned foods a small amount was left unattacked and this residue contained most of the tin. The author suggested that the protein-tin complex was so firmly bound that it would be eliminated directly by the digestive processes and not figure in any physiological action attributed to tin salts.

As already stated, the majority of the determinations of the tin content of canned foods were made before the advent of the open-top can, which by reason of its construction eliminates all contamination of the can contents by solder, and in addition, in the case of lacquered cans, reduces the area of exposed tinplate in contact with the can

TABLE XVI

Distribution of Tin between the Solid and Liquid Portions of Various Canned Foods

(Bigelow)

Variety of food	Milligrams tin per kilogram in :		
	Liquor	Total sample	Drained solids
Cranberries	33	170	254
Raspberries	39	194	294
Cherries	52	107	163
Peaches	86	193	251
Pears	99	130	151
Plums	43	125	180
Shrimps	67	224	381
Spinach	35	86	131

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TABLE XVII

Distribution of "Free" and "Combined" Tin between the Solid and Liquid Portions of Various Canned Foods

(*Bigelow*)

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Variety of food	Age of sample		Milligrams tin per kilogram in :			Soluble tin in drained solids (a)	Insoluble tin in drained solids (b)	Soluble tin in total sample (a)
	Yr.	Mo.	Total sample	Drained solids	Liquor			
Aspara-		8	280	322	200	193	129	196
gus	1	5	433	489	252	248	241	249
	2	7	470	554	238	229	325	233
Lima		9	80	99	46	38	61	41
beans	2	9	173	254	40	33	221	35
String		2	124	169	63	60	109	62
beans		7	130	174	64	61	113	63
	1	3	299	442	97	93	349	95
	1	8	250	382	102	98	284	100
	2	6	434	658	132	127	531	130
Wax		3	93	143	39	38	105	39
beans		7	116	176	52	50	126	51
		10	139	251	55	53	198	54
	1	3	230	391	72	69	322	71
	1	8	217	359	87	84	275	86
	2	4	347	616	88	85	531	86

(a) The figures in these columns are doubtless higher than they should be as they are based on the assumption that the tin of the unfiltered liquor is all in solution.

(b) For the reason given in footnote (a), the figures in this column are doubtless lower than they should be.

contents. In this connection Adam and Horner[12] stated that in an A.2½ can made from standard tinplate, with a tin coating weight of 28oz. of tin per basis box, the amount of tin on the inside of the can would, if completely dissolved, give a tin concentration of about 1,200 p.p.m. This, therefore, represents the maximum possible tin content it would be possible to attain if the interior of the can was completely detinned.

In Chapter 3 the effect of oxygen on the rate of internal corrosion of the can has been described, and it has been shown that oxygen acts as an accelerator. It would be expected, therefore, that the

initial rate of corrosion would be rapid until the residual oxygen in the can has been removed. This is, in fact, the case, and Horner[13] has stated that this process takes from five to thirty days, depending on the amount of residual oxygen left in the can after exhausting and also on the type of can, plain cans using up oxygen more rapidly than lacquered cans.

Contrary to expectations, the pH value of the can contents is not the governing factor in the dissolution of the tin coating, the results of Adam and Horner[12]. Tables XVIII and XIX providing evidence of this phenomenon.

TABLE XVIII

Tin Content of Canned Fruits
Effect of Sugar Syrup : Cans Stored 10 months (1936)
(*Adam and Horner*)

Fruit	Covering liquid	pH	Tin Content Mg. per kg.	Type of Can
Gooseberries	Water	2.94	77	Plain
	Syrup	2.88	75	..
Loganberries	Water	2.88	13	Lacquered
	Syrup	2.79	11	..
Blackcurrants	Water	3.00	36	..
	Syrup	2.98	39	..
Blackberries	Water	3.16	7	..
	Syrup	3.07	4	..

Such products as pumpkin, asparagus, shrimps and rhubarb, with widely varying pH values, are particularly corrosive : the latter, if packed in plain cans, will often remove almost the whole of the tin coating, and double lacquered cans are, therefore, always used for this product ; under these conditions Adam and Horner[12] state that the tin content will seldom rise above 100 p.p.m. even after two years' storage.

The use of lacquered cans as a means of preventing discoloration and sulphur staining has already been described in Chapter 3, and it is also a very effective method of reducing the amount of tin dissolved by the can contents. The results of Adam and Horner[12],

TABLE XIX

Tin Content of Canned Fruits

Effect of Temperature of Storage in Plain and Lacquered Cans
Storage 14 months

(Adam and Horner)

Fruit	Storage Temperature °F.	pH	Plain cans Mg. per kg.	Lacquered cans Mg. per kg.
Gooseberries	Normal	2.80	98	28
	72	2.80	151	35
	95	2.80	200	51
Strawberries	Normal	3.58	—	14
	72	3.58	—	20
	95	3.58	—	64
Raspberries	Normal	2.91	—	15
	72	2.91	—	40
Loganberries	Normal	2.70	—	14
	72	2.70	—	22
	95	2.70	—	33
Blackcurrants	Normal	3.12	—	72
	72	3.12	—	85
	95	3.12	—	147
Greengages	Normal	2.95	99	—
	72	2.95	153	14
	95	2.95	283	35
Plums, Pershore	Normal	2.92	95	16
	72	2.92	142	30
	95	2.92	393	52
Damsons	Normal	3.03	—	31
	72	3.03	—	40
	95	3.03	—	90

Table XX, show how efficient this method can be. The use of double lacquer will reduce the amount of tin dissolved by another fifty per cent.

Other factors of importance are the time and temperature of storage of the filled cans. Elevated temperatures result in an increase in the rate of corrosion and a corresponding increase in the amount of tin found in the can contents. The amount of tin in the can contents also increases with time of storage, but after an initial period, immediately after closing, in which the tin content rises at a high rate, further action takes place more slowly. Both these facts are

TABLE XX

Tin Content of Canned Vegetables
Effect of Time of Storage in Plain and Lacquered Cans

(Adam and Horner)

S.R. = Sulphur-resisting lacquer.   D.F. = Double coating, fruit lacquer.

Vegetable	Type of Can	Storage Time months	Tin content	
			Range Mg. per kg.	Average Mg. per kg.
Asparagus	Plain	12	270–327	292
	,,	24	331–335	333
	S.R.	60	48–60	54
Beans, Broad	,,	34	17–18	18
Beans, Dwarf	Plain	21	(93–100)	(97)
	D.F.	12	20–29	24
	,,	24	7–12	10
Beetroot	,,	10	7–19	14
	,,	27	12–17	15
Brussels Sprouts	S.R.	42	11–13	12
Carrots	Plain	9	85–115	99
	,,	27	115–171	152
Celery	Plain	9	73–110	92
	,,	24	91–97	94
Mushrooms	S.R.	28	12–15	14
Peas, Fresh	Plain	22	(22–27)	(25)
	S.R.	13	4–21	13
	,,	22	17–34	24
	,,	72	18–20	25
Peas, Dried	S.R.	30	11–14	13
	,,	60	13–25	19
Potatoes (Young)	Plain	9	33–40	37
	S.R.	9	6–13	10
Potatoes (Old)	Plain	6	14–17	16
	S.R.	6	13–15	14
Spinach	D.F.	26	8–22	15
Turnips	S.R.	26	4–9	6
Beans in Tomato Sauce	Plain	9	125–130	128

illustrated by the results of Adam and Horner[12], shown in Table XXI. The tin content of canned vegetables is usually very low, with the exception of canned asparagus, which is frequently found to contain a high proportion of tin. Typical values for the tin content of the majority of canned vegetables are shown in Table XX, after Adam and Horner[12].

TABLE XXI

Tin Content of Canned Fruits

Effect of Time and Temperature of Storage in Plain and Lacquered Cans

(Adam and Horner)

Fruit	Storage time. months	Plain cans		Lacquered cans	
		Normal store	Stored 95°F.	Normal store	Stored 95°F.
		Mg. per kg.	Mg. per kg.	Mg. per kg.	Mg. per kg.
Gooseberries	3	86	114	12	19
	7	100	192	22	44
	9	94	291	25	48
Cherries. White	3	24	65	12	14
	6	30	117	6	22
	9	35	185	30	—
Plums. Pershore	3	51	68	6	16
	6	66	129	8	21
	9	83	209	13	30
Greengages	3	38	80	7	15
	6	—	115	—	15

Although fruits and vegetables are the most likely products to contain significant quantities of tin, other products also attack the interior of the can. Fish and marine products, for example, often contain accelerating substances ; shrimps have been shown by Bigelow and Bacon[14] to contain monomethylamine which readily attacks tin and iron, while the addition of sauces containing tomato puree to herrings often causes extensive detinning, especially when plain cans are used. Meat products do not in general exert any marked detinning action. and it seems likely that any tin which is dissolved will be present in the form of a tin-protein complex which is not, therefore, likely to have any physiological effect.

Milk and milk products have not attracted much attention from the aspect of their tin content, but Horner[15] found that the tin content of canned sweetened condensed milk was small and did not increase appreciably during a period of twelve months' storage. The tin content of canned cream and unsweetened evaporated milk increased fairly rapidly during the first few weeks of storage, but after this preliminary period, further attack was slow. Like other canned foods. the tin content was reduced by internal lacquering, but as the amount

of tin dissolved in a plain can is small it is not usual to employ lacquered cans for milk or milk products.

There is no statutory limit for the tin content of foods, but following the report of Buchanan and Schryver[8], made over thirty years ago, a figure of 286 p.p.m. has become the recognised maximum value in the United Kingdom for all foods. It should be noted that the limit of 286 p.p.m. was suggested as the result of a number of analyses made on food packed in a type of container which is no longer in use and which favoured a high tin content ; also, no cognisance was taken of the formation of tin-protein complexes, by which a considerable proportion of the tin content of the food is rendered insoluble and unattacked by the digestive processes.

Canning technique has been developed to such an extent that there is little possibility of the tin content of canned foods reaching a value in excess of the present recognised limits unless by accident, for example the use of plain instead of a lacquered can.

The present recognised standard, although no undue hardship in the majority of cases, might well be modified in the light of present day knowledge of the toxicity of tin salts, and if raised to 300 p.p.m. there would be very few cases of infringement, and, at the same time, no increased danger to public health.

It is interesting to note that the standard adopted in the United States is 300 p.p.m., and the fact that millions of cans of food are consumed annually without deleterious effects is additional evidence to show that the possibility of tin poisoning is extremely remote.

The fixing of a statutory limit for the tin content of canned foods is long overdue, as by so doing the manufacturer has a figure to act as a guide, a case of infringement is readily recognised and the public interest is safeguarded.

Arsenic

Although arsenic is unlikely to occur in canned foods its presence in sea water and soil renders it a possible contaminant of the raw materials used in the canning industry. Arsenical sprays used on fruit and vegetable products may be a source of contamination as also may a number of the chemicals used in the food industry.

The work of Chapman and Linden[16] has demonstrated the presence of considerable quantities of arsenic in crustaceous marine products, prawns containing up to 114 p.p.m., mussels 119 p.p.m. and Portuguese oysters 70 p.p.m. It has, however, been shown that the arsenic is present as an organic complex which is unaffected by ordinary reagents or the digestive processes.

There is, therefore, little cause for concern regarding the arsenic content of canned foods provided care is taken to remove the residues

of arsenical sprays and to ensure that any chemicals used in food processing are arsenic free.

Copper

Most food products contain a certain amount of copper but rarely in sufficient quantity to cause concern. Clayton[17] compiled the figures shown in Table XXII for the natural copper content of a variety of foods. Copper is also present in the human organism, the highest concentration being found in the liver where quantities up to 34 p.p.m. have been found. The toxicity of copper has not been well established and Elvehjem[18] has pointed out that it is used for the treatment of pernicious anaemia and is a necessary constituent of the human organism for blood regeneration.

TABLE XXII

Natural Copper of Various Foods

(*Clayton*)

Food	Copper Content p.p.m.
Eggs	1.1–1.19
White potatoes	6.5
Yellow potatoes	4.1
Black grapes	8.1
Navy beans	10.45
Lima beans	8.6
Yellow corn	16.6
Beef liver	16.0
Beef kidney	2.4
Beef tongue	1.2
Cow milk	0.5–0.85
Human milk	0.5–0.6
Butter	0.6
Cheese	0.6

The practice of using copper salts for the colouring of peas gave rise to copper contents ranging from 55–265 p.p.m. and the use of these salts has now been prohibited.

The use of copper vessels in food factories, particularly where acid or salted foods are handled, should be avoided as the copper surface is readily attacked and the copper salts so formed may contaminate the food.

A case of greyish discoloration in the skins of canned peas and the covering liquor has been shown by Adam and Dickinson[19] to be due to copper contamination caused by the action of a film of salt left overnight in contact with copper brine pans.

Copper is frequently found in tomato and tomato products being derived from three sources as follows :—

(1) The natural copper content of the tomato.
(2) Copper salts contained in sprays used as fungicides during growth.
(3) The use of copper vessels in the preparation of the tomato or tomato puree.

Samples of imported tomato puree and pastes have been found by Cockburn and Herd[20] to contain as much as 246 p.p.m. of copper, calculated on the dry solid content of the material.

The natural copper content of tomatoes has been found by Greenleaf and Isham[21], and Weber and Maclean[22] to vary between 7 and 24 p.p.m., while Horner[23], who added copper sulphate to the soil of pot grown tomatoes, suggested that the natural copper content is unlikely to exceed 40 p.p.m. even when the soil is heavily contaminated with copper as the result of the regular use of copper-bearing sprays.

Further contamination by copper during processing can be reduced to a minimum by the use of stainless steel equipment.

In 1939 a limit of 100 p.p.m. of copper on the dry weight of tomato puree was set and at the same time it was announced that the limit would be reduced to 50 p.p.m. and finally to 20 p.p.m. in the future.

In view of the inevitable copper content of tomatoes Horner[23] examined a number of samples of imported tomato puree and reached the conclusion that while with proper washing and the elimination of copper equipment the limit of 50 p.p.m. could be attained, any reduction to 20 p.p.m. would be impracticable.

Apart from tomato products the canner has little to fear regarding contamination with copper ; an exception, however, is the case of milk and milk products, where copper salts act as accelerators for the oxidation of the milk fats and rancidity develops more rapidly than would normally be the case if copper salts were absent.

Another effect of copper is that it accelerates the destruction of vitamin C and it is, therefore, important to eliminate copper contamination when dealing with products containing this vitamin.

Lead

This metal is recognised as a dangerous poison and is cumulative when absorbed by the human organism. Most of its salts are affected by the digestive processes and it is also absorbed through the digestive tract.

In a very complete investigation of the lead content of foods Monier-Williams[24] showed that small quantities of lead are normally present in some foods and also pointed out that the bones of a normal

person may contain up to 50-100 p.p.m., the blood 0.2 p.p.m. and the urine 0.05 p.p.m.

In marine products Chapman and Linden[25] showed that large quantities of lead may be found ; up to 25.0 p.p.m. in lobster, for example, but again as in the case of arsenic the lead is present in a physiologically inert form.

With the use of the fully soldered can there was always the possibility of contamination of the contents of the can by way of the solder used in sealing. This possibility has now been largely eliminated by the almost universal use of the sanitary can whose construction renders contamination of the can contents by solder virtually impossible. The canner has, therefore, little to worry about regarding the possibility of contamination from the can.

The possibility of contamination of the food during preparation or by the addition of chemicals such as dyestuffs etc., must, however, be considered.

Contamination resulting in large scale rejections has been reported in the case of imported canned sardines ; Lampitt and Rooke[26] examined nearly 600 samples and found that 30 per cent contained from 10-90 p.p.m. of lead. On investigation it was found that the fish were being contaminated by the grills on which they were steamed before packing ; the grills were made of tinned iron wire which had been "retinned" by dipping in molten solder with a high lead content, the steam condensing on the grills removed the lead and contaminated the fish. When grills coated with block tin were used the lead content of the fish was reduced to 7-10 p.p.m. The limit for lead in imported sardines has now been reduced from 20 to 5 p.p.m., and will ultimately be reduced to zero.

Lead arsenate is used as a spray for fruits and may, therefore, be present as a contaminant of the fruit used for canning, but provided proper precautions are taken to wash the fruit effectively before use no difficulty should be experienced from this source.

It will be seen from the above that provided proper precautions are taken to ensure the raw materials used in canning are lead free the canner need not be unduly concerned about the lead content of canned foods.

Savage[27] has stated, for example, that except as a special hazard, as in the case of the sardines mentioned above, there is little danger from lead poisoning in canned foods as packed by the modern cannery.

Zinc

There appears to be little evidence that the continued ingestion of small quantities of zinc has any deleterious effects on the human organism.

Zinc is found both in unprocessed foods and the human organism. Clayton[17] has stated that the daily zinc intake of the normal adult is of the order of 15 mgrms.

Analyses by Bertrand and Benzon[28] show that the zinc content of foods is very variable, peas containing up to 44.5 p.p.m., while potatoes contained 5.0 p.p.m.

The use of galvanised vessels in food factories is practically extinct and there is therefore, little possibility of canned foods becoming contaminated with zinc.

Aluminium

Although aluminium is not at present used to any great extent for the fabrication of cans for processed foods, the increased output and corresponding reduction in price of the metal, coupled with the development of new alloys with properties approximating to that of tinplate, may well result in its use for some of the less corrosive foods.

In addition, aluminium plant and vessels are frequently used in the preliminary preparation of many foods before canning, and the canner, has, therefore, a strong interest in the toxicity of this metal.

Even though the concensus of opinion, among those who have investigated the toxicity of aluminium, is that the element and its salts are devoid of toxic properties in the quantities likely to be ingested by the human body, the fact that the metal is liable to attack by dilute acids and alkalies combined with the increased use of aluminium cooking vessels has kept the toxicity controversy alive.

Aluminium is very widely distributed in nature and occurs in the majority of foods, and also in the human organism.

Meunier[29] determined the aluminium content of a number of plants and found values varying from 10-60 p.p.m. The same author also showed that the aluminium content of beef varied from 1-8 p.p.m., while Bertrand and Levy[30] found onions to contain 90 p.p.m., potatoes 76 p.p.m. and carrots 22-30 p.p.m.

In the human organism Kehoe, Cholak and Story[31] found quantities ranging from 0.04 p.p.m. in the brain to 59.0 p.p.m. in the lungs, all values being obtained on the wet tissue. The average daily intake from food has been estimated by Beal, Unangst, Wigman and Cox[32] to be rather less than 10 mg.

In experiments to test the cumulative properties of aluminium it has been generally demonstrated that the metal is not retained in the human body, the amount excreted corresponding to the intake. Recent determinations by Schoular[33] have confirmed that there is no significant accumulation of aluminium in the human organism from the amounts likely to be found in food.

The toxicity of aluminium has been studied at considerable length

but it does not appear to be known with any certainty what quantity constitutes a lethal dose, most experiments having been done by feeding tests on animals or by subcutaneous injection, methods which do not always give results strictly comparable with that of oral administration to the human organism.

The use of the chloride, sulphate and hydroxide as drugs for internal use is described in the British Pharmocopoeia, the doses being similar to those prescribed in the case of iron and tin salts, thereby indicating that the toxicity of aluminium salts is of the same order as these two metals.

Woldman and Polan[34] administered a 5 per cent aqueous suspension of aluminium hydroxide to 30 of their patients for periods varying from 2-4 years, the quantity corresponding to about 2 grms. of the hydroxide per diem, no abnormal symptoms were observed.

Aluminium combines with the phosphate ion to form aluminium phosphate, which is not soluble in the digestive juices, thus preventing the utilisation of the phosphate content of foods. In this respect, however, it is no different from salts of iron and Cox, Dodds, Wigman and Murphy[35] have shown that this effect only appears when the aluminium content of food is as high as 1,400 p.p.m.; a figure far in excess of that likely to be encountered in any type of food.

Aluminium containers have been used for fish packing and Lunde[36] has shown that the amount of aluminium dissolved by the contents of the can varies from 4.86 to 64.0 p.p.m. with an average value of about 35.0 p.p.m. after two years storage. Lunde, Aschehoug and Kringstad[37] conducted experiments in which rats were fed with a diet of sardines containing 84 to 100 p.p.m. of aluminium. Control rats had an identical diet except that the sardines were freshly packed in tinplate. The experiments were continued until the birth of the fifth generation there being no difference between the rats fed on the diet containing aluminium and the control rats. This result confirms the work of McCollum, Rask and Becker[38], who fed rats on a diet containing the equivalent of about 0.06 per cent aluminium, and found no difference in the growth rate, reproduction or general health compared with rats fed on an aluminium free diet.

The final conclusion is that aluminium and its salts in the quantities likely to be present in foods as a result of the use of aluminium plant or containers offer no danger to health.

From the preceding paragraphs it will be seen that provided proper care is taken to eliminate any metallic contamination which may be present on the raw materials before canning and that contamination during processing is avoided by the use of stainless steel or aluminium plant and equipment there is no reason to suppose that the final product will be excessively contaminated with undesirable metals.

The question of the imposition of limits to the metal content of foods is somewhat loose and Table XXIII compares the limits which are established in the United States of America, where definite standards are laid down, with those of the United Kingdom where no statutory limits exist, although certain recommended values which are the result of long experience in the analysis of foods are upheld by the Courts.

TABLE XXIII

Limits for the Metal Content of Canned Foods

Metal	Established Limit in U.S.A. p.p.m.	Recommended Limit in U.K. p.p.m.
Arsenic	2.0	1.4 (in solids)
Lead	2.0	5.0 (imported sardines only)
Copper	15.0	100.0 (imported tomato products only)
Tin	300	286
Zinc	100	None

It will be seen from the above table that the limits of metal content are much more closely defined in the U.S.A. than in the United Kingdom.

In an extensive review of the literature concerning the occurrence, nutritional value and toxicity of a number of elements which occur in small quantities in food, Calvery[39] divides such metals into three classes : nutritive trace elements—cobalt, copper, iron, iodine, manganese, and zinc ; non-nutritive, non-toxic trace elements— aluminium, beryllium, boron, chromium, silicon, strontium, tin, titanium and nickel ; non-nutritive toxic trace elements—silver, bismuth, cadmium, fluorine, mercury, lead, arsenic, antimony, barium, bromine, selenium, tellurium. molybdenium, vanadium and thallium. It must be emphasised that this review refers to the presence of very small quantities of metals such as may be found in nature.

In fixing permissible limits consideration must be given to the natural metal content of many foods, the form in which the metal is present, whether as a relatively insoluble organic complex or in an active form and finally, the extent to which a particular food is a staple article of diet.

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CHAPTER 11

SPOILAGE IN CANNED FOODS, AND ITS PREVENTION

ALL types of canned foods are subject to change after processing, in most cases, however, these changes take place at such a slow rate that unless the canned food is stored for an abnormal length of time, or under adverse conditions no noticeable deterioration is observed by the consumer. In a few instances changes during storage may enhance the quality of the pack, with certain fish packs in oil, for example, it is only after storage that the full flavour of the pack is developed due to the gradual penetration of the oil into the fish.

In the majority of cases, however, changes after processing are detrimental to the quality of the pack, and in some cases a stage is reached at which the contents of the can are inedible or aesthetically unattractive and "spoilage" is said to have occurred.

Spoilage can be divided into two distinct types, firstly, physical and chemical, and secondly micro-biological. Determination of the particular type of spoilage is often an important means of locating errors in canning technique and in the choice of raw materials.

Spoilage may assume many different forms, in some cases the effects are readily seen by the untrained eye, while in others only to the trained observer will spoilage be apparent.

Of the more easily identifiable forms the following are the most common :—

Swells. A frequent result of spoilage is the production of gas, and pressures may be developed in the can of sufficient magnitude to distend the ends and even cause it to burst. A can with the ends bulged due to gas pressure is known as a "swell" or a "blown" can.

A swell passes through various stages of development; in its initial stages, the can is normal in appearance but when it is struck, particularly on the end seam, one end springs or flips out, but may be pushed back with light pressure. A can in this condition is known as a "flipper." Over-filling or faulty exhausting as well as gas pressure due to spoilage, produce this phenomenon.

At a later stage in the development of a swell one end of the can may bulge and on forcing the bulged end back the other end will bulge, a can in this condition is known as a "springer."

In a still more advanced stage of the development of a swell both ends of the cans will dome but they may still be returned to normal by exerting light pressure, although they will spring back to their former position when the pressure is released. A swell at this stage is known as a "soft" swell.

Finally, a condition is reached when both ends are bulged and it is no longer possible to push in either end, even momentarily, and the can is described as a "hard" swell and is in a most advanced stage of spoilage. Further development of the hard swell usually leads to bursting of the can.

Hydrogen Swell. This is a special class of swell in which the gas pressure is due to hydrogen generated by corrosion of the can by its contents. Hydrogen swells pass through the same stages as an ordinary swell.

Although usually sterile hydrogen swells cannot be distinguished without examination of the can contents from swells produced by micro-biological action and must, therefore, be considered unfit for consumption. This type of swell occurs most frequently with fruits and other acid products which corrode the interior of the can. The causes and prevention of hydrogen swells have already been considered in Chapter 3.

Flat Sour. The contents of a can may undergo micro-biological spoilage without the generation of gas, although, a sour flavour may develop due to the production of acid. Spoilage of this type is known as "flat sour" spoilage. As thermophilic organisms are frequently involved in this type of spoilage it is of considerable economic importance, particularly as it cannot be detected until the can is opened. The most frequent cause of this type of spoilage is under-processing and it is, therefore, extremely important in the case of packs in which flat sour producing organisms are likely to be present to ensure that processing is adequate.

Leakers. When a can exudes part of its contents it is classified as a "leaker." Leakers may result from a variety of causes of which the following are the most common :—

(1) Faulty seaming.
(2) Internal or external corrosion.
(3) Mechanical damage during handling.
(4) Nail holes caused by faulty nailing of cases.
(5) Excessive internal pressure due to micro-biological action or corrosion, the pressure eventually being sufficient to burst the can.

Buckling. Cans in which distortion has taken place, frequently as the result of improper cooling technique. The cans often resemble

swells, and although the ends can usually be returned to normal by light pressure the seams are often badly strained and the contents of the can become spoiled due to the ingress of micro-organisms through the strained seams.

The distortion sometimes produces a small ridge or peak on the can end and the phenomenon is, therefore, frequently known as "peaking."

Panelling. The reverse of buckling, being caused by excessive external pressure and most frequently seen in large sized cans with too great a vacuum. The effect is also observed in cans which have been pressure cooled where the external pressure has been in excess of the internal pressure in the can.

Physical and Chemical Spoilage

The most important types of spoilage which occur under this heading are :—

(1) Discoloration of the can and/or its contents.
(2) Corrosion of the can.
(3) Spoilage due to faulty technique.
(4) Foreign flavours.
(5) Undesirable textures.

Discoloration. Losses due to this type of spoilage are chiefly concerned with the appearance of the can contents, as with certain products discoloration is particularly prone to occur thereby prejudicing the pack in the eyes of the consumer.

Reference has already been made to discoloration resulting from the liberation of hydrogen sulphide from protein containing materials, and little more need be said on this subject except to point out that the trouble can be entirely overcome by the use of suitable lacquers for coating the interior of the can.

A further cause of discoloration is the contamination of raw materials during preparation by the use of unsuitable vessels ; one of the earliest examples of this type of spoilage is reported by Bigelow and Miller[1] who found that canned corn containing as little as one part per million of copper was blackened. It was subsequently found that the copper had been picked up by the corn from copper pans used during its preparation. A somewhat similar phenomenon in the case of canned peas has been described by Adam and Dickinson[2], a greyish deposit on the skins of the peas and a greyish suspension in the covering liquor was observed and afterwards proved to be due to contamination with copper derived from brine pans. Similar effects in the case of certain marine products have been reported by Jarvis[3]. The blackening of canned products, not normally associated with

sulphur staining, was found by Cruess[4] to be due to the use of a rubber conveyor belt containing sulphur compounds which contaminated the canned food and caused blackening.

The effect of water containing dissolved mineral salts on the turbidity of brine and syrup has already been referred to, and in this connection Morris[5] mentions a case in which canned rhubarb was spoiled by deposits of calcium oxalate produced from the reaction of calcium salts contained in the liquid filling the cans and the oxalic acid contained in the rhubarb.

An entirely different type of discoloration to the above occurs when certain products are overprocessed. With light coloured foods such as canned dairy products and certain marine products this effect is particularly noticeable.

In the case of evaporated milk Hunziker[6] attributes the discoloration to reactions between lactose and the milk proteins.

The importance of the accurate control of processing conditions in the case of products sensitive to excessive heating has been pointed out by Jarvis[3] with particular reference to canned marine products such as crab.

An effect similar in character to over-processing may be produced if cooling is not properly carried out. A considerable quantity of heat is retained by insufficiently cooled cans and if these cans are stacked or cased while hot, cooking of the contents may go on considerably longer than was originally intended, producing all the effects associated with over-processing. This is known as "stack burning" and may easily be prevented by proper cooling technique.

The development of a pink coloration in canned pears and peaches, which were not thoroughly cooled after processing is mentioned by Cruess[4], thus illustrating that even with fairly light processes deterioration may take place if cooling is not properly carried out.

Corrosion. The many types of corrosion phenomena have been fully discussed in Chapter 3, and little more need be said except to point out that corrosion of the can either externally or internally is responsible for a considerable percentage of the losses which occur in the canning industry each year, particularly among fruit packs. During the last few years, however, considerable progress has been made in the study of the corrosion of tinplate, the formulation of new lacquers for the internal coating of cans, and the development of chemical and other methods of producing a protective coating on the inside of the can. Provided the canner takes advantage of this new knowledge, losses due to corrosion can be reduced to a minimum.

Faulty Technique. Included under this heading are such factors as :—under or over-filling, insufficient exhausting, faulty seaming,

under or over-processing, abuse of cans during handling resulting in dents and damaged seams, etc.

In most cases faults of this kind are due to carelessness or ignorance. Carelessness can only be eliminated by constant vigilance and insistence on exactness and a methodical approach to the every day problems of a cannery.

Since its inception the canning industry has made great technical advances, particularly during the last decade, and information on the latest developments is freely available to the industry through the medium of research associations, the research departments of the can makers and the many journals and periodicals devoted to food technology. There is, therefore, no reason for any canner to be uninformed and employ methods which do not take full advantage of modern knowledge.

Foreign Flavours. Unhygienic conditions of storage, preparation and filling may all be contributory causes to the development of the foreign or "off-flavours," which frequently result from micro-biological action.

In many cases delay in preparing and processing the food on its arrival in the cannery leads to fermentation or other micro-biological action with the result that "off-flavours" develop. Some products may acquire a flavour from the containers in which they are delivered to the cannery. A case is reported[7], for example, in which peaches and apricots acquired a flavour from the pinewood boxes in which they were transported.

Metallic contamination acquired by the use of unsuitable equipment may result in the development of a "metallic" flavour. Milk and milk products are especially sensitive in this respect and in addition to the above mentioned "metallic" flavour, the salts of some metals act as accelerators of the oxidation of milk fats producing a tallowy flavour. Rice[8] has observed that this effect is particularly noticeable in milk contaminated with copper or its salts.

Contamination of the interior of the can with oil, as may occur if equipment is over lubricated, must be avoided otherwise unpleasant flavours will be developed.

Before the use of water base emulsions for the preparation of can end lining compound an unpleasant flavour known as "gout de petrole" was sometimes produced in certain products, notably sardines and pineapple, due to the insufficient evaporation of the solvent used to dissolve the rubber in the lining compound.

Entirely different in character is the development of foreign flavours due to over-processing, a burnt or "cooked" flavour being usually produced, particularly noticeable in milk and milk products. Hunzi-ker[6] points out that the development of the "cooked" flavour in

canned milk is accompanied by a darkening in colour of the milk. Certain products containing cereals may also develop a burnt flavour if processed for too long a time, or at too high a temperature.

Flavour is one of the most important characteristics of all foods and it is essential for the canner to maintain a constant check on the flavour of his pack by the frequent examination of samples. It should, therefore, be the practice in every cannery to hold regular tasting panels at which samples of current production and of suggested new packs are examined.

The organisation of tasting panels and the training and testing of members of the panel have been discussed by King[9], and by Knowles and Johnson[10] who used dilute solutions of such substances as salt, sucrose, tartaric acid, glutamic acid and caffeine to determine the upper and lower thresholds of taste. The reliability of organoleptic tests as commonly carried out at tasting panels has been studied by Crist and Seaton[11] who found that vision played an important factor in offsetting the inconsistencies of the other senses, thus supporting the theory that "eye-appeal" is an important factor in the selection of food.

A system of scoring should be adopted, such as that suggested by Platt[12] or by Adam[13], and it will be found that when experience has been gained extremely small differences in flavour will be detected by the panel.

Undesirable Textures. As in the case of flavour there are no precise units by which texture in foods may be measured, although instruments have been developed such as the tenderometer referred to in Chapter 6 which measures the resistance to shearing of certain foods such as peas and beans from which an indication of the relative tenderness may be obtained.

Many products are characterised by a particular texture and the consumer readily detects any departure from standard.

A smooth texture is particularly desirable in canned milk, but it is sometimes found that sweetened condensed milk develops a "sandy" texture which is sufficient to make it unsaleable. The "sandy" texture according to Hunziker[6] is due to the formation of relatively large sized lactose crystals greater than 10 microns in length. One of the main factors determining the crystal size is the technique adopted in the cooling process, and shock cooling, seeding with fine lactose dust, and vigorous agitation, are all methods designed to bring about the production of the desired size of crystal.

Similar to the above is the development of a gritty deposit in evaporated milk, which has been shown by Mojonnier and Troy[14] to be due to the presence of tricalcium citrate. Hunziker[6] states that the temperature of storage of the milk is a controlling factor in the

formation of this gritty deposit. If the milk is stored at 45°F. or below no deposit is formed as the salts responsible possess the peculiar property of being less soluble at higher temperatures.

Deposits of a crystalline nature are not common in canned foods, but mention must be made of the occurrence of struvite crystals in certain canned marine products as reported by Clark and Clough[15]. These crystals of magnesium ammonium phosphate closely resemble glass, and Clayton[16] has stated that complaints are sometimes received by the canner of glass particles being found in a can. These complaints may usually be easily dispelled by demonstrating that the crystals are soluble in a dilute acid such as vinegar. Several workers have studied the crystals notably Merwin[17], and Ayres[18] and these workers have shown that the crystals can be readily distinguished from glass both by microscopical and crystallographic methods. The formation of the crystals in canned lobster has been attributed by Hollett[19] to the introduction of sea water containing magnesium compounds, at some stage in the canning process, which react with the inorganic phosphorus and ammonia in the lobster to form large amounts of struvite, the limiting factor being the availability of magnesium. The use of salt or brine containing excessive quantities of magnesium compounds would presumably have the same effect.

The effect of the hardness of water used in canneries on the texture of certain products is mentioned in Chapter 6, calcium salts contained in the water have a toughening effect, peas and beans being the most affected. This hardening effect is turned to advantage in packing products which are liable to breakdown during processing, calcium chloride, for example, is frequently added to potatoes and tomatoes to produce a firmer texture, a procedure referred to in more detail in Chapter 12.

The careful control of processing is important in packing some of the more delicate products such as the soft fruits where over-processing may result in the production of a pulp instead of clean whole fruits.

As in the case of flavour, regular tasting panels are a valuable means of ensuring that there is no departure from the normal texture associated with a particular product.

Micro-biological Spoilage

Of the several types of spoilage to which canned foods are subject, that produced by micro-organisms is one of the most important. The subject is extremely complex in view of the number of spoilage organisms involved, and the many different types of food now packed in cans. The main causes of spoilage, however, may be classified under the following headings :—

(1) Improper handling of the food before processing, and the use
     of heavily contaminated raw materials.
(2) Under-processing.
(3) Contamination after processing.

Any development of spoilage organisms before processing must be
avoided, and there is a very real risk in allowing any undue length of
time to elapse between filling the can and processing, particularly if
the food is in a partially warm condition. A case of spoilage of this
kind is reported by McClung and Wheaton[20] in the canning of boiled
beef in which the cans were "blown" when they came from the retort
after processing. The authors considered that the meat was contam-
inated with the spoilage organisms when received at the canning plant
and that they were not destroyed during the parboiling process which
preceded filling. After filling the cans were vacuum closed, and the
spoilage organisms rapidly multiplied in the warm meat, during the
period between filling and processing, generating sufficient gas to
produce "blown" cans.

Although an extreme case, the above example serves as an
illustration of the importance of avoiding delays between filling and
processing, and in fact at all stages in the preparation of raw materials
for canning.

Strictly any pack which becomes defective due to the presence of
spoilage organisms which have survived processing may be termed
under-processed, but as pointed out by Baumgartner[21] the primary
cause of spoilage may be due to many factors apart from errors in
the formulation of the process.

A process which may be satisfactory under one set of operating
conditions may be inadequate where different conditions of processing,
plant sanitation, etc., obtain. Baumgartner[21], therefore, distinguishes
between spoilage resulting from an unduly heavy infection through
some fault in the operation of the plant, and that resulting from
processing conditions below the accepted standard, he further points
out that as a general rule spoilage due to under-processing in a
mechanically sound can is characterised by the presence of a single
type of organism rather than a number of different organisms.

Contamination of the can contents after processing usually occurs
during cooling, particularly water cooling. In this type of spoilage
the organisms involved are usually of widely varying kinds, although,
as Cameron and Esty[22] have stated, the acidity of some products
exerts a selection action only permitting the growth of acid tolerant
organisms. The same authors also point out that the organisms
associated with this type of spoilage are frequently of a type which
could not have withstood heating, thereby clearly indicating that

they must have been introduced at some stage after processing took place.

In connection with the investigation of leaker spoilage Baumgartner[21] emphasises that, although, microscopical examination may indicate the presence of cocci or other non-heat resistant organisms these may have been present before processing and have been destroyed by the process, and it is, therefore, important that microscopical examination should be combined with culturing to determine if the organisms observed are viable.

The importance of chlorinating cooling water as a means of controlling post-processing contamination of cans has been referred to in Chapter 8 and little need be added except to repeat that chlorination must not be regarded as a means of compensating for sub-standard seams, and that before chlorination is adopted steps must be taken to confirm that spoilage is due to contaminated cooling water and that the seams are within the prescribed limits.

Types of Spoilage Organisms. There are many different types of organisms involved in the spoilage of canned foods and it is not within the province of this volume to describe them all in great detail. It is, however, desirable that some consideration should be given to the main types of spoilage organisms likely to be met, and also to a few of the rarer types or organisms which are of interest to the canner. For a more extensive treatment of the micro-biology of canned foods the reader is referred to the works of Tanner[23], Jensen[24], and Baumgartner[21].

Some of the many factors affecting the development of spoilage organisms in canned foods have been considered in Chapter 7 and it has been shown that the pH value of the environment is an important factor in determining the type of organism likely to be found as the causative agent in the spoilage of canned foods. It is not surprising, therefore, that the pH value should be used as a means of classifying foods into groups with respect to the type of spoilage which is likely to occur.

Grouping of this type was first suggested by Bigelow and Cameron[25] who, while recognising that all fruits and vegetables were acid to some extent, divided them into three primary groups :—acid, semi-acid and non-acid. The upper limit of the acid range being fixed at pH 4.5, that of the semi-acid range being pH 6.0 and the non-acid range above pH 6.0. Modifications to this grouping have since been made by Cameron and Esty[22] who suggested four groups as follows :—

Group 1. Low Acid—pH 5 and higher. This group includes meat and marine products, milk, and certain vegetables such as peas, asparagus and spinach.

Group 2. Medium Acid—pH 5 to 4.5. Included in this group ar[e]
meat and vegetable mixtures and such packs as spaghett[i,]
macaroni and certain soups.

Group 3. Acid—pH 4.5 to 3.7. Pears, pineapples, figs and oth[er]
fruits are in this group, also tomatoes.

Group 4. High Acid—pH 3.7 and below. This group contain[s]
such products as rhubarb, grapefruit, citrus juices an[d]
pickles.

In discussing this system of classification Baumgartner[21] points ou[t]
that the principal line of demarcation is at pH 4.5, below whic[h]
it is generally recognised that the growth of *Clostridium botulinu[m]*
is inhibited.

Processing under pressure is, therefore, essential for all foods with [a]
pH value higher than 4.5, and as stated in Chapter 7 it is the commo[n]
practice to insist that all processes for medium and low acid food[s]
should be sufficient to ensure the destruction of the spores o[f]
Clostridium botulinum.

Among the low acid and medium acid foods the organisms mos[t]
frequently involved in spoilage due to under-processing are those i[n]
the thermophilic group. These organisms are characterised by thei[r]
ability to form spores which withstand relatively high temperatures,
while their optimum growth temperature is at about 55°C. The fact
that the optimum growth temperature is about 55°C. assumes special
importance in the case of packs which are to be stored in warm or
tropical climates as these conditions are often ideal for the growth of
thermophiles.

Thermophiles are usually divided into three groups based on their
action on the can contents, a system described by Cameron and
Esty[22] as follows :—

The first group are the so called "flat sour" organisms which produce
spoilage by the production of acid without generating gas. Cans
affected with these organisms show no outward change as the ends
remain flat.

The type species of this group is *Bacillus stearothermophilus*, first
described by Donk[26] and later studied by Cameron and Esty[27].

The economic importance of the "flat sour" group of organisms is
considerable as they are facultative anaerobes and, as pointed out by
Baumgartner[21], the temperature range for their growth is wider than
for some of the other groups of thermophiles, growth at 37°C. being
common, while slow development at 25°C. has also been observed.

From the canners point of view an important consideration is the
fact that no outward sign of spoilage is detectable until the can is
opened by the consumer. It is, therefore, of paramount importance to

ensure that raw materials are free of "flat sour" organisms and that processing conditions are such as to ensure the destruction of any of these organisms which may be present in the can.

The second group of thermophiles, in order of their economic importance, is that of the thermophilic anaerobes not producing H_2S. These organisms are of considerable importance in the spoilage of medium acid foods. The type species of this group is *Clostridium thermosaccharolyticum* described by McClung[28].

The organisms in this group produce large quantities of gas, mainly hydrogen and carbon dioxide, frequently accompanied by a sour butyric odour. In Great Britain losses due to this group of organisms have not, according to Baumgartner[21], been very serious as storage temperatures are not normally favourable for their development, although, in warmer climates considerable trouble is sometimes encountered.

The third and last group of thermophilic organisms, and least important from the economic aspect, are the anaerobes which produce H_2S, the type species being *Clostridium nigrificans* described by Werkman and Weaver[29].

Cans infected with this organism do not often show any outward signs of spoilage as the H_2S generated is usually soluble in the can contents which become blackened as a result.

In Great Britain according to Bashford[30] spoilage by this organism is extremely rare, and while Cameron and Esty[22] have stated that a few isolated cases of heavy spoilage have occurred in America the incidence is so low that it is not considered of any great commercial importance.

The relatively high heat resistance of the spores of thermophilic organisms has naturally resulted in considerable attention being paid to the development of methods designed to reduce the incidence of spoilage by this group of organisms. By virtue of their high heat resistance it is sometimes impossible in the case of certain packs to give a sufficiently rigorous process to ensure the destruction of the spores of the organisms without seriously affecting the quality of the finished pack. A great deal of attention has, therefore, been given to tracing the origin of thermophiles and also to methods of preventing their entry and development in canneries. This work has shown that soil is frequently a carrier of thermophiles as also are starch, sugar, and various spices. Certain types of cannery equipment provide "dead" spaces in which thermophiles may accumulate and multiply and it is, therefore, important when choosing new equipment to ensure that all parts are easily accessible for cleaning. The build up of thermophilic organisms and their occurrence in raw materials is considered in greater detail in Chapter 6.

From the economic aspect the group of organisms next in importance to the thermophilic group is that of the mesophilic spore forming anaerobes, of which *Clostridium botulinum* and *Clostridium sporogenes* are typical examples of the putrefactive sub-group, while *Clostridium butyricum* and *Clostridium pasteurianum* are typical of the saccharolytic sub-group.

Of the above organisms *Clostridium botulinum* is by far the most important as it is responsible for the occurrence of botulism in man, an illness which has a high mortality rate.

The development of methods of controlling this organism has naturally been looked upon as a matter of paramount importance. The literature on the subject is extensive and a summary of the occurrence of the organism and its most important characteristics has been made by Baumgartner[21], also by Tanner[23], and Dack[31], while many workers such as Meyer and Dubovsky[32], Meyer, Leighton and Buxton[33], and Haines[34] have investigated the distribution of the spores of the organism in the soil in many parts of the world.

An interesting factor influencing the growth of *Clostridium botulinum* in certain canned vegetables is the concentration of tin salts in the can contents. Scott and Stewart[35] observed that growth was inhibited in plain tinplate cans, but not in lacquered cans such as are normally used for packing vegetables. Experiments by the same authors[36] showed that the concentration of tin required to prevent growth varied with different vegetables, approximately 150 p.p.m. being required in the case of beetroot and about 30-60 p.p.m. in the case of carrots.

Clostridium botulinum was one of the first organisms of importance to the canning industry shown to have a high degree of resistance to heat, and as stated in Chapter 7 has been used as a yard-stick for assessing the processing of low and medium acid foods. In the last few years, however, organisms have been isolated which have an even greater heat resistance than that of *Clostridium botulinum*, such as those described by Baumgartner and Wallace[37], for example, which were shown to resist processes with lethal values several times that required for the destruction of *Clostridium botulinum*. Processes have, therefore, had to be stepped up accordingly.

Apart from the above mentioned organisms of high heat resistance there are a number of others associated with the spoilage of low and medium acid foods. among which may be mentioned the group of spore forming aerobes of the genus *Bacillus* which are widely distributed in nature.

These organisms are generally credited with a low degree of heat resistance but Baumgartner[21] points out that some have a considerable resistance to heat and quotes the work of Nichols[38] who found that

many strains of aerobic spore formers isolated from milk products withstood heating for 20 minutes at 120°C.

The various sub-divisions of the aerobic spore forming bacteria have been very fully set out by Lanbach, Rice and Ford[39].

A curious example of the action of a metal as a contributory factor in the micro-biological spoilage of canned food has been studied by Cameron, Esty and Williams[40]. The spoilage took the form of a black discoloration which developed in sliced beetroot, the effect only being observed when an abnormally large quantity of iron was present in the liquor in the can. The organism responsible was named *Bacillus betanigrificans* and in a phosphate buffer solution at pH 7.0 a concentration of 150,000 spores per millilitre survived heating at 110°F. for 20 minutes, but was destroyed after 25 minutes, while in beet juice at pH 5.5 no survival was observed in the shortest heating time of five minutes.

It is not suggested that the above organism has any great economic significance, but it is described as an example of the many and varied types of spoilage which may occur in canned foods.

Turning now to the Acid and High-acid products which include such things as tomatoes, pears, plums, soft fruits, citrus fruits, rhubarb, etc., we find that the number of common spoilage organisms is greatly reduced as compared with that associated with the spoilage of the low acid and medium acid foods. References to spore forming organisms are chiefly confined to those sometimes found in tomatoes and tomato products such as *Clostridium pasteurianum* described by Townsend[41] and *Bacillus thermoacidurans* described by Berry[42] and by Stern, Hegarty and Williams.[43] The first organism is a saccharolytic anaerobe while the latter is a "flat sour" type capable of existing in an acid environment and is the more important of the two as it is a thermophile, although, according to Cameron and Esty[22], it is less resistant than the thermophiles associated with the low and medium acid foods.

Although it is usually considered that *Clostridium botulinum* is only likely to occur in foods with a pH value greater than 4.5, Slocum, Welch and Hunter[44] report a case of botulism resulting from the consumption of home canned tomatoes, in this instance, however, the tomatoes were grossly under sterilised, and the technique of processing not that which would be adopted in commercial practice.

As far as yeasts and mould are concerned, little trouble is encountered in the majority of canned foods, an exception being sweetened condensed milk and evaporated milk. Savage and Iunwicke[45], for example, found that the swelling of cans of sweetened ⸱densed milk was due in most of the cases they examined to the ⸱ence of yeasts, while Hammer[46] assigned the name of *Torula*

lactis condensi to an organism he isolated from a "blown" can of sweetened condensed milk.

Sweetened condensed milk is also subject to spoilage by moulds such as *Aspergillus repens* which was found by Rogers, Dahlberg and Evans[47] to be the causative organism in the development of lumps of yellowish brown curd. These mould "buttons," as they are called, may cause considerable trouble as the organisms are widely distributed in nature and can gain access to the milk at many different points in the cannery.

A mould which has caused some spoilage in canned fruits is the species *Byssochlamys fulva* first reported by Olliver and Smith[48], and up to the present time, apparently confined to Great Britain. Fruit infected with this mould disintegrates and the cans sometimes dome due to the production of carbon dioxide. A disquieting feature of this mould is the relatively high heat resistance of the ascospores and the fact that it is able to grow under reduced oxygen tension. Olliver and Smith[48] state that the ascospores survive heating for 30 minutes at 88°C. while Hull[49] states that canned fruit requires heating to at least 190°F. and preferably to 195°F., as measured at the centre of the can, to ensure destruction of the most resistant spores.

Olliver and Rendle[50] report that the mould is present on the fruit in the fields and that it is probably associated with the soil.

Further information on this mould has been given by Gillespy[51] who found that the maximum heat resistance of the spores occurred at pH 5 while resistance at pH 3 was much greater than at pH 7, and in later work[52] that the lethal concentration of sulphur dioxide required for the destruction of the mould is a function of the pH value.

Although, as stated above, *Byssochlamys fulva* has not as yet been reported in America a species of *Penicillium* has been isolated by Williams, Cameron and Williams[53] from canned blueberries, and from the soil of the fields in which blueberries were grown. The scelerotia of one strain of this mould showed considerable heat resistance requiring 300 minutes at 85°C. before being destroyed. The mould is also capable of growth in a high vacuum.

Although the organisms mentioned above do not possess the same heat resistance as some of the thermophiles, their control in canned foods presents a somewhat difficult problem as they produce spoilage in products which cannot withstand prolonged heating without some loss in quality and breakdown in texture. Emphasis is, therefore, placed on eliminating the organisms from the raw materials, and the cannery, rather than on increasing processes to destroy the organisms already in the can.

Prevention of Spoilage

An attempt has been made in the preceding pages of the present Chapter to outline some of the more important causes of spoilage in canned foods, and in conclusion the following recommendations are made as being among the principal methods of spoilage control :—

(1) All raw materials must be thoroughly examined and handled with the greatest possible regard to hygiene.

(2) All equipment must be kept scrupulously clean.

(3) Raw materials should not be held in a warm condition longer than is absolutely necessary, and should be handled as rapidly as possible to avoid the possibility of micro-biological spoilage.

(4) The fill of all cans should be carefully controlled.

(5) The exhausting process should be sufficient to produce a good vacuum.

(6) During seaming operations the quality of the seams should be checked at frequent intervals.

(7) Processing should take place as soon as possible after closing.

(8) The cooling process should be carried out in such a manner that the cans are left sufficiently warm to dry off surplus moisture, but not hot enough to cause "stack" burning.

(9) Where spoilage has definitely been shown to be due to contaminated cooling water some method of chlorination as suggested in Chapter 5 should be adopted.

(10) The finished cans should be stored in well ventilated warehouses and high storage temperatures should be avoided.

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CHAPTER 12

SOME RECENT DEVELOPMENTS

ALTHOUGH the canning industry was founded in the early part of the nineteenth century, it was not until the early 1930's that it began to assume a significant place in the economy of the United Kingdom. In the U.S.A., however, canned foods had already found a place in the nation's diet and it was natural, therefore, that this latter country should be responsible for much of the early development work in the industry.

Before the second World War the canning industry in the United Kingdom was entering upon a phase in which it was beginning to reap the benefit of technical advances made in the many centres of research throughout the world. With the coming of war, however, many interesting projects had to be abandoned in order to concentrate the maximum effort on producing canned foods for the Services, and to a lesser extent for the civilian population. This enforced regimentation was not without its good points as many of the canners were for the first time brought under regular technical control and benefited accordingly, and, as in most industries, the problems of war brought in their train many developments of considerable peacetime value and it is with these developments that the present Chapter is largely concerned.

Alternative Can Making Materials

Although hot dipped tinplate has been the principle raw material used for the fabrication of cans since the inception of the industry it has certain inherent disadvantages which have encouraged the search for other materials, a search which was carried out with redoubled energy during the recent war when shortages of tin became a matter of considerable concern to friend and foe alike.

The most important disadvantages of tinplate as a can making material are :—

(1) As a multi-layer material composed of two dissimilar metals it is subject to corrosion due to electro-chemical action.
(2) Fracture of the tin coating may occur during fabrication thus exposing the steel base and rendering the can more susceptible to corrosion.

(3) With certain products discoloration of the interior of the can or of the contents may occur which, although quite harmless, renders the pack aesthetically unattractive.

Although tinplate possesses the above disadvantages it is nevertheless a very satisfactory material for can making as is shown by the fact that no serious competition has been encountered from alternative materials since the inception of the industry.

Efforts have, however, been made from time to time to replace tinplate with other materials, but until the recent war these efforts met with little success.

During the war a great deal of work was carried out on the use of lacquered or bonderised steel by such workers as Lueck and Brighton[1], Mathiesen[2], and Jakobsen[3], but, although, some extremely interesting results were obtained it cannot be said that the results were such as to warrant the use of any of these materials when tinplate is freely available.

Probably more progress in the production of cans from lacquered steel was made in Germany than in any other country, but here again it seems unlikely that the cans so produced could compete economically with the conventional tinplate can. A comprehensive review of the German can making industry, with particular reference to the developments which took place during the war, has been made by Maier[4] and by Howard.[5]

The two materials which seem to show most promise as alternatives to hot dipped tinplate are aluminium and electro-tinplate and the discussion of alternatives will be confined to these two materials.

Aluminium. The use of this metal is by no means new as Nickelsen[6] refers to the packing of brisling and sardines in aluminium cans at an exhibition held in Oslo in 1918. It was not, however, until about 1930, when the A/S Norsk Aluminium Company carried out extensive investigations on the use of aluminium sheet for making food cans, that any great interest was shown in this new can making material. It is somewhat significant that the first move in the use of aluminium was made by the producer of the metal rather than by the canning industry.

A survey of the use of aluminium for can making in Norway has been made by Kleumann[7], while Lunde[8] carried out experiments to determine the amount of aluminium dissolved by various foods, and reached the conclusion that the use of aluminium was in no way deleterious to health.

The composition of aluminium used for can making has been given by Mathiesen[2] as 99.5 per cent Al, but the same author states that an alloy containing 1 per cent Mn. is also used.

The advantages offered by aluminium as a can making material have been summarised by Nickelsen[6] as follows :—

(1) Aluminium can be produced from freely available raw materials.

(2) The aluminium industry is now well established and has rapidly expanded during recent years.

(3) Aluminium may be easily rolled into sheet or strip and is easy to fabricate into cans.

(4) Aluminium cans are light in weight ; slightly more than one-third the weight of tinplate cans of similar dimensions.

(5) Corrosion of the can does not produce coloured corrosion products as in the case of tinplate where black sulphides are sometimes produced.

(6) There is no metallic taste or smell.

(7) The metal is non-toxic.

(8) Aluminium cans are easy to open.

On the other hand aluminium has several disadvantages which the same author lists as follows :—

(1) Aluminium cans are not very resistant to corrosion by acid fruits or vegetables without lacquering or some other form of protection.

(2) Aluminium is a softer metal than tinplate and aluminium cans must, therefore, be handled with more care than is necessary with tinplate cans.

(3) Special precautions are necessary during sterilisation to avoid permanent distortion of the seams.

An additional disadvantage which is not mentioned above is that aluminium cannot be soldered on a high speed body maker and aluminium cans must, therefore, be made by some method which does not involve soldering.

Before the recent war the cost of aluminium for can making compared unfavourably with that of tinplate, even when the increased value of aluminium scrap was taken into consideration. During the war, however, the productive capacity of aluminium throughout the world was increased to meet the demands of the aircraft industry, with the result that what was once a comparatively high priced material is now very little dearer than tinplate, and what is more, is freely available.

The vast majority of aluminium cans are fabricated by deep drawing, in a similar manner to that used for fish cans made from

tinplate, but the use of this new material opens up another method of can fabrication, namely, impact extrusion.

In this method a disc of aluminium known as a "slug" is placed in specially shaped die as shown in Fig. 106. The punch which is of the same diameter as the desired internal diameter of the finished can then descends and gives the slug a sharp blow, whereupon the aluminium flows in an upward direction conforming to the contour of the punch, thus forming a seamless container which only requires trimming and flanging and, in some cases, the addition of strengthening beads and lacquering before being ready for use. A description of impact extrusion is outside the scope of this volume and the reader is referred to the work of Pearson[9] for further details of the process.

PRODUCT

BLANK
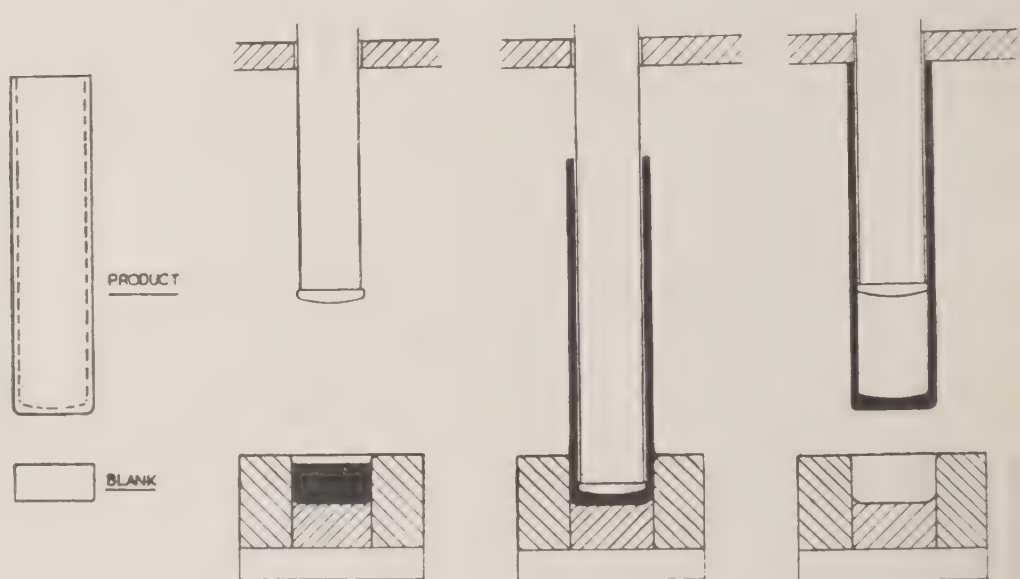
Fig. 106. Impact extrusion of can.
(*Courtesy "Sheet Metal Industries"*)

Extruded cans were used on a small scale by the Germans during the war, but the high cost of production has so far prevented their wider adoption. Typical extruded cans are shown in Fig. 107. These cans are all of 1 kilogram capacity and in most cases are sprayed internally with lacquer.

As already stated the difficulties of soldering aluminium and its alloys, has so far prevented the manufacture of cans from aluminium similar in character to the conventional open top tinplate can and most cans have been made by deep drawing, a process for which aluminium is well suited. Typical Norwegian cans of this type are shown in Fig. 108.

The corrosion of aluminium cans has been fully studied by Jacobsen and Mathiesen[10] who point out that it is due to the thin film of oxide

FIG. 107. Aluminium cans made by impact extrusion.

FIG. 108. Some examples of aluminium cans as made in Norway.
(*Courtesy A S Nordisk Aluminiumindustri*)

which is always present on the surface of aluminium, that it is possible to use this metal as a can making material.

To obtain added protection the natural oxide film is often thickened by anodising, a process which may be carried out either on the sheet or strip, or on the fabricated container. Where still greater corrosion resistance is required a lacquer film may also be applied by any of the methods described in Chapter 4. Cans made by impact extrusion must, of course, be lacquered after fabrication.

Cans made from aluminium are more easily dented than cans made from tinplate and this fact has a considerable influence on the methods adopted in their handling, not only in the cannery, but also in the hands of retailers and consumers. In the cannery care must be taken to avoid dents caused by rough handling and particular attention must be paid to the double seaming operation, although, when properly carried out the seam obtained is just as sound a double seam as that on a tinplate can.

In order to prevent permanent distortion of the aluminium can pressure must be applied during processing and cooling, and special retorts have been developed in Norway for this purpose. A typical installation is shown in Fig. 109. These retorts also embody a large insulated storage tank into which the hot water from processing is pumped as the cold water for cooling is admitted. When cooling has
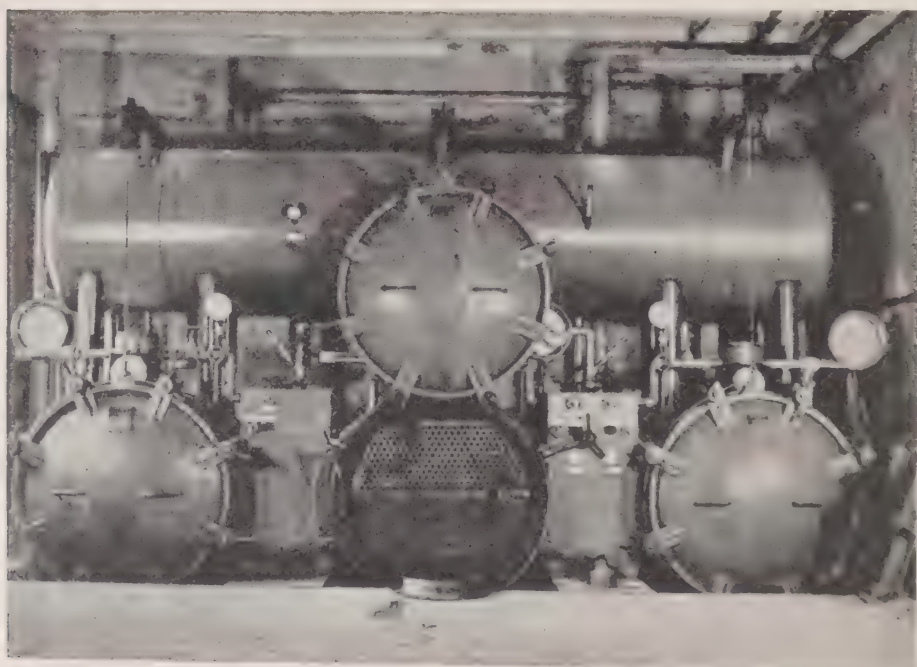
FIG. 109. A "Hamjern" over-pressure retort as used in Norway for the processing of aluminium cans

(Courtesy A/S Nordisk Aluminiumindustri)

been completed and the retort recharged with another load of cans for processing the hot water contained in the storage tank is returned to the retort. In this manner hot water is saved and the coming-up time of the retort reduced.

The increase in the use of aluminium during recent years in Norway is well shown by Table XXIV, after Nickelsen[6], which shows the tonnage of coiled aluminium strip used by the Norwegian can making industry.

TABLE XXIV

Annual Consumption of Coiled Aluminium Strip for Food Can Manufacture in Norway

(*Nickelsen*)

Year	Weight of strip
	Tons
1932	32
1933	138
1934	226
1935	332
1936	272
1937	334
1938	328
1939	574
1940	607
1941	627
1942	937
1943	1136
1944	781
1945	929
1946	1685
1947	1512
1948	1926

The same author also lists the following foods as being packed in aluminium or its alloys :—

(1) In aluminium-manganese alloy : Kippered herring.
(2) In anodised aluminium : Brisling and Sild Sardines in Oil, Shrimps, Natural Crab and Crab Paste, Fish Balls, Cod Roe, Fish Cakes, Mussels, Peas, Green Beans, Mushrooms, Condensed Milk, Meat Products, etc.
(3) In anodised and lacquered aluminium : Sardines in Tomato Sauce, Spinach, Asparagus, Anchovies, Meat Products, etc.

It will be seen from the above list that an extensive range of products can be packed in aluminium, a high proportion in anodised aluminium cans. In addition to the Norwegian work referred to above the use of aluminium for can making has also been referred to by Smith[11] and by Thompson[12].

In conclusion it can be stated that there are no technical difficulties in the use of aluminium as a material for can making other than the fact that present methods of production tend to be too slow and, therefore, costly.

Electrolytic Tinplate. The production of tinplate base by the continuous strip rolling process directed attention to the possibility of developing methods of continuous tinning, and the electrolytic tinning process is the final outcome of this work.

The development of the acid and alkaline electro-tinning baths has been reviewed by Lippert[13], and a description of the commercial production of electrolytic tinplate has already been given in Chapter 2, but nothing has, as yet, been said about its applications, its possibilities, and its limitations.

The use of electrolytic tinplate for can making received considerable encouragement during the war when supplies of tin had to be conserved, as the process permits the production of tinplate with much lighter tin coatings than is possible with the hot dip method.

Resulting from the urge to use electrolytic tinplate considerable experimental work has been carried out to determine the service life of containers made from this material. Lueck and Brighton[14], for example, found that tinplate with a coating weight of 8 ounces per basis box possessed very poor corrosion resistance to moist packs, but that when lacquered satisfactory service life could be obtained.

The use of electrolytic tinplate is still the subject of much experimental work, but the following conclusions reached by Lueck and Brighton[14] appear to represent the present position :—

(1) Electrolytic tinplate has not fully met expectations with regard to its corrosion resistance to the mildly corrosive fruits and vegetables.

(2) Severe localised corrosion may occur and pitting develop at the sites of any small discontinuities in the lacquer coating.

(3) Without an interior coating of lacquer electrolytic tinplate with a coating weight of 8 to 12 ounces per basis box is unsatisfactory for most foods of high moisture content.

(4) With non-corrosive products fully lacquered cans of electrolytic tinplate have proved satisfactory.

At the outset difficulty was experienced in soldering electrolytic tinplate, but this problem was soon overcome by the use of

silver-lead solder instead of the tin-lead variety commonly used for hot dipped tinplate.

In connection with the investigations carried out on the service life of electrolytic tinplate containers the above authors made use of the flip vacuum method of following the changes taking place in the internal pressure of containers under test. This method consists in applying a vacuum to the outside of a container and observing the point at which the end flips out. It must be emphasised that this method does not give an absolute value for the vacuum, as the point at which the end flips out is dependent not only on the internal vacuum in the can, but also on several other factors, all of which are characteristic of a particular can. The method does, however, provide a useful means of following changes taking place in the internal pressure of a can over a time period.

Although the introduction of electrolytic tinplate, and its continued improvement in quality as the result of technical advances would seem to presage the eventual elimination of the hot dipping process, this is by no means a foregone conclusion. The main advantages of the electrolytic tinning process as compared to hot dipping are that the former process permits the production of extremely thin and even tin coatings, and it also makes possible the tinning of the strip produced by the continuous strip rolling mills. It is, however, quite possible that at some future date improvements in the hot dipping process will result in the production of more even coatings and also the development of a method of hot tinning continuous strip.

The production of more even coatings has already attracted much attention, and an experimental machine has been described by Hoare[15] in which improvements in the drive of the rollers of the tinning machine resulted in the production of a tinplate coating without the transverse irregularities commonly found in hot dipped tinplate, and with lower porosity and enhanced appearance.

In spite of improvements in hot dipping technique, however, there is no doubt that electrolytic tinplate has come to stay, as is shown by the fact that the majority of tinplate rolling mills have installed electrolytic tinning equipment. A review of the first commercial plant in the United Kingdom has recently been given by Patterson[16].

Can Making

Apart from developments in the manufacture of cans from substitute materials few new developments have taken place in the United Kingdom and the U.S.A. in the technique of can making during the last few years.

In Germany, however, the industry underwent several radical changes during the recent war when conventional methods of can

making had to be abandoned due to the shortage of tinplate an
other essential raw materials.

These developments have been fully described by Maier[4] and b
Howard[5], and include the use of untinned strip steel, post-lacquerin
of cans by spraying and by flushing, the use of synthetic resins fo
the manufacture of lacquers and end lining compounds, etc. Althoug
extremely interesting and valuable from the technical angle thes
developments are not likely to be of any great commercial interes
as in most cases the cost of the cans so produced was considerabl
greater than that of cans made by standard methods.

The almost complete eclipse of the pack rolling process by th
continuous strip method and the development of the electrolyti
tinning process in the U.S.A., and to a lesser extent in the Unite
Kingdom, has focused attention on the possibility of using the coile
strip in body makers and end stamping presses instead of sheet:
thereby avoiding the necessity of cutting the strip into sheets an
also saving a considerable amount of handling.

The use of coils of strip was adopted on a large scale in German
during the war, in some cases the first coating of lacquer bein
applied at the rolling mill thus acting as a rust preventative durin
storage and while the strip was in transit between the rolling mi
and the can maker.

The possibility of using strip in this manner has engaged th
attention of most of the manufacturers of can making machinery
but with the exception mentioned above has not found muc
application, although it undoubtedly has considerable possibilities fo
the future.

It seems likely that with the continued development of electrolyti
tinning processes and the replacement of pack rolling by continuou
rolling methods the use of coiled strip will increase in the future.

Post-Lacquering of Cans. The value of lacquering of car
as a means of securing added corrosion resistance has already bee
emphasised, and considerable work has been done on the lacquerin
of cans after fabrication both by spraying and by flushing. Mathison
has patented a process in which a fabricated container is filled wit
lacquer and then emptied, and drained in such a manner as to ensur
that the interior of the can is covered with an even film of lacquer
Here again the exigencies of war forced the Germans to adopt flus
and spray lacquering on a large scale in spite of the economic draw
backs which attended the processes.

In all processes of post-lacquering the main problem to be solved i
that of handling and drying large numbers of cans after lacquering
and if high rates of production are to be obtained the size of th
drying equipment becomes extremely large. Some idea of the dryin

ovens used by the Germans may be obtained from Fig. 110 which shows a lacquering and bonderising unit for cans capable of handling up to 5,000 cans per hour. The development of a quick drying lacquer would be of considerable assistance in post-lacquering as it would enable much smaller drying units to be used. Lacquers based on synthetic resins may at some future date supply a lacquer with the desired properties. The present position, however,. is that, although post-lacquering offers several advantages the mechanical difficulties of the process have so far militated against the large scale adoption of the process, but once these difficulties have been overcome there is little doubt that the process will find widespread application.
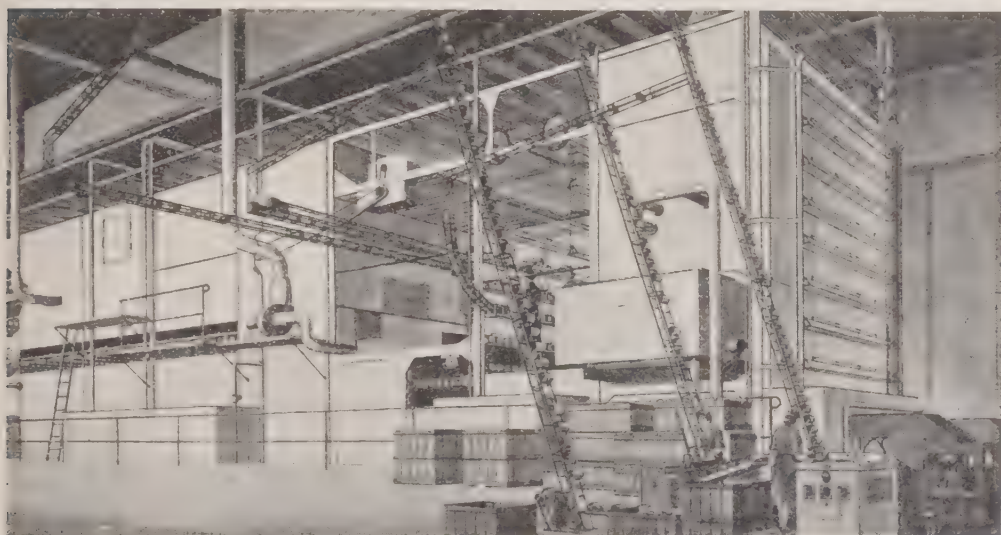
FIG. 110. Lacquering and drying unit for bonderised cans.

Lithographing of Cans. Although no new concept the use of lithographed cans increased considerably during the war and containers for the many millions of solid meat packs produced in the U.S.A. were usually decorated by this method.

Lithographing eliminates the use of the paper label which is always liable to become detached or torn, and furthermore, provides a very attractive form of decoration. The printing of tinplate is not a new process, but the production of a series of printing inks which would withstand processing at the relatively high temperatures used for canned meat packs presented many difficulties.

Considerable care is required in handling lithographed cans, particularly after processing when the ink tends to be rather soft and easily damaged. One difficulty arising from the use of lithographed cans is the fact that each can is suitable for only one product

owing to the external decoration, and large stocks of cans mus
therefore, be held if a range of different products is packed. Whe
long runs of the same product are common, however. this is not
serious objection.

Alternative Can Shapes. During the war when shipping spa
was at a premium frequent references were made to the possibility
using cans of square or rectangular section in order to avoid th
wastage of space which inevitably occurs in shipping round cans. Th
use of square or rectangular cans is not new as corned beef has bee
packed in this type of can for many years, and more recently th
spiced ham packs produced in the U.S.A. To pack all products i
this type of can would, however, mean a complete re-organisation
the can making and the canning industries and would also slow dow
production, as great use is made of the fact that the round can
easily transported by gravity, a procedure impossible if a square
rectangular can is used.

Electronics in the Canning Industry

The rapid development of electronic devices and their applicatio
to many industrial processes during the last fifteen years tended t
obscure the fact that in many cases considerable development wor
is necessary before the application of these devices can become
commercial success. This is especially true in the case of the cannin
industry.

The application of electronic devices in the canning industry ma
be divided into two groups :—

      (1) Regulating and controlling various operations.
      (2) Heating as in blanching and processing.

Reference has already been made to the use of photo-electric cel
in controlling the flow brightening of electro-tinplate. These cells ma
also be used for counting various objects, or for stopping machiner
should a fault occur, and for many other purposes.

An application of interest to the canning industry is the sorting
beans, a process based on the differences in the percentages of red an
green light reflected by good and bad beans.

A review of the uses of electronic devices as controllers an
regulators has been made by Urbain and LeRoy Clardy[18] wit
particular reference to the food industries. The control of temperature
pH, levels of liquids, time cycles, and humidity being among th
several factors mentioned as being capable of electronic control.

It is, however, the use of high frequency alternating currents fo
heating that is of most interest to the canning industry, and the basi
principles of electronic heating have been reviewed and described b

many authors among whom may be mentioned Kinn[19], Wenger[20], and Sherman[21] who have all treated the subject from the food technologists' point of view.

There are two basic methods of electronic heating, the first, induction heating used for the heating of conductors such as metals is of little interest to the canner, but the second method, dielectric heating, which can be applied to non-conductors offers many possibilities not only to the canning industry but to many other branches of the food industry.

The principal advantage of dielectric heating is that large masses of non-conductors may be heated rapidly and uniformly the heat being generated within the material independently of conduction or convection currents, although these may play a part if heating is prolonged. Benjamin and Ecklund[22] point out that if successfully applied to the processing of canned foods electronic heating might reduce the time required from hours to minutes, thereby securing improvement in flavour and quality of the product and realising all the advantages offered by high temperature-short time processing.

The same authors emphasise, however, that the cost of electronic equipment is high and that the process is, therefore, only likely to find application where the improvement in quality of a relatively high priced product might be sufficient to justify the increased cost involved in electronic heating.

Cost of equipment increases rapidly when high frequencies are required. Jackson[23], for example, considers that electronic heating will cost about 12 times that of steam heating and points out that a cannery processing a hot filled product at about 200 cans per minute requires approximately 1.5 million B.T.U's per hour, assuming no heat loss, and that this would require an electronic heater of 500 kw capacity which would cost of the order of £50,000.

There are, in addition, many difficulties to be overcome before electronic heating methods are sufficiently developed to replace the conventional methods of sterilisation at present in use.

The requirements for the successful application of electronic methods to the processing of canned foods have been listed by Jackson[23] as follows :—

(1) Heating must be uniform throughout the product. Arcing or local over-heating must be avoided otherwise scorching or the development of a burnt flavour may occur.

(2) The rate of heating must be sufficiently rapid to reach a temperature of approximately 250°F. within a few minutes in order to obtain the maximum improvement in quality, and also to permit high speed production.

(3) Equipment must be suitable for operating at pressures up
the maximum likely to be developed within the contai
during processing.

(4) The product to be sterilised must be heated in hermetica
sealed containers, or it must be heated and transferred a
sealed aseptically in previously sterilised containers.

(5) As equipment and operating costs will be high the efficiency
the process must be high also, in order that the finisl
product may be competitive with products processed
conventional methods.

The need for uniform heating is a very serious obstacle to
application of electronic heating to the processing of canned foo
With homogeneous materials such as plastics uniform heating
not difficult to secure, but food is far from homogeneous, proba
the nearest approach to homogeneity being found in soups and sim
products. In other packs, however, a mixture of solids in a liq
is frequently encountered and each of the several materials may h
at a different rate. Benjamin and Ecklund[22], for example, rep
that in experiments they carried out with ham a temperature
260°F. was indicated by one thermometer, while another a li
over one inch away indicated only 190°F., and on further examinat
it was found that some of the fat was scorched, while the lean was ra

Experiments tend to show that the use of higher frequenc
overcomes this difficulty, Meyer and Stotz[24], for example, found t
in the blanching of vegetables by electronic heating increasing
frequency to 150 megacycles reduced scorching.

To obtain the full advantage of electronic heating the rate
heating must be rapid otherwise the improvement in quality will n
be sufficient to justify the increased cost which is at present involv
and heating times of 0.5 to 5.0 minutes are mentioned by Benjar
and Ecklund[22] using a special type of container which consis
of a Pyrex tube 90 mm. in diameter fitted with metal ends wh
acted as the two electrodes. Immediately after heating
container was immersed in a tank of hot water at 250°-255°F. fo
sufficient period to sterilise the inner walls of the container. T
authors state that this procedure was necessary as the inner walls
the glass container received only the heat derived by conduction fr
the product and consequently were much cooler than the cen
of the can. The container was finally cooled.

In addition to the heating effect of high frequency alternat
currents the possibility that micro-organisms might be destroyed
some lethal action independent of the heating effect has also be
investigated by several workers. Fleming[25], Hasche, and Leumig

and Hicks and Szymanowski[27] have all studied the biological action of these high frequency currents, but the results so far obtained are by no means conclusive, at any rate as far as food spoilage organisms are concerned, and further study is required in this field.

The advantages of electronic heating have been given considerable prominence during the last few years, but less has been said about the many difficulties which must be overcome before the process can be regarded as a commercial success when applied to the processing of canned foods, and in conclusion a summary of the position in the light of the knowledge available at the present time is given below :—

(1) Electronic heating both in the preparation, and in the actual processing of canned foods offers considerable theoretical advantages.

(2) The process is at present limited to the treatment of foods which are essentially homogeneous in character.

(3) The capital and maintenance costs of the equipment are high and can only be offset by the production of a product which by virtue of improvement in quality will command a correspondingly higher price.

(4) The practical application of electronic heating would almost certainly necessitate a special type of container which would again add to the cost of the product.

It will be seen, therefore, that the rapid replacement of steam heating by electronic heating is unlikely, but further study of the problem appears to be justified as the advantages offered by an economical method of electronic heating are considerable.

Self Heating Can

The possibility of providing some means of heating a can of food which could be used where the normal methods of heating were not available was mentioned at an early date in the history of canning. A survey of the patent literature reveals that a patent[28] was granted in 1898 for a can of this type which consisted of a can containing the food to be heated surrounded by a similar can of larger diameter, the annular space between the two being filled with quicklime to which water was added when it was desired to heat the can contents.

Self heating cans may be divided into two classes :—

(1) External heating element.
(2) Heating element internal.

The majority of self heating cans fall into the first group and t
heating material is placed in the space formed between two cylindri
containers, the inner container being filled with food.

The chief disadvantage of this arrangement is that heat penetrat
to the centre of the can is slow and a considerable proportion of t
heat generated is lost due to the large area of the outer contai
exposed to the atmosphere.

In the second group these disadvantages are overcome by plac
the heating element at the centre of the can.

Considered from the production viewpoint containers in the fi
group are to be preferred, but the disadvantages of this type of c
outweigh any production difficulties. Many different types of h
generating compositions have been suggested, ranging from
relatively simple mixture of lime and water to more complica
mixtures such as aluminium with cupric carbonate, barium chlori
and aluminium sulphate.

All mixtures of the above types require the addition of wa
to start the reaction, but during the recent war a demand develop
for a self heating can which could be used under a wide rai
of conditions and climates. The introduction of water, therefc
became impossible and an alternative reaction had to be found
heating the can. Finally, a sa
factory means of achieving this
found and patented by Caldwell a
Ashcroft[29].

The final form of the self heat
can is shown in Figs. 111 and 1
It will be seen that the heat
composition is contained in a me
tube running down the cen
of the food container. The compc
tion is ignited by a match or
lighted cigarette after first remov
the cap covering a short length
fuse. Heating takes about t
minutes. Two holes are puncl
in the lid of the can before light
the fuse to permit the escape
any steam generated during
heated process.

Cans of this type have be
used for soups, cocoa and ot
beverages which heat mainly
convection.

FIG. 111. Self-heating can showing
internal construction and central
heating cartridge.

(Courtesy H. J. Heinz Co. Ltd.)

FIG. 113. Self-heating can showing one method of ignition.

(*Courtesy H. J. Heinz Co. Ltd.*)

Improvement in Quality

During the war period when maximum production was required it was impossible for the canner to do much to improve the quality of his product, but now that the selling of canned goods is once more becoming highly competitive, quality will become an important selling point. The general public are more food conscious than ever before, and there is little doubt that when presented with a free choice of goods the lower quality foods will find little acceptance.

It is not surprising, therefore, that far-seeing canners are always looking for new methods and new techniques which will raise the quality of their products, as it is only by so doing that they can hope to retain their position in the future.

The "high-short" processing technique has already been mentioned and it seems likely that this method, in which high temperatures are used for a correspondingly shorter time, will find increased application in the future, in spite of the fact that the present processing technique may have to undergo radical changes before the system becomes a success.

The most difficult problem in the application of the high-s
technique is to secure the rapid heat penetration which is essenti
the full benefits are to be obtained. Various methods of achie
this objective have been described by Ball[30], who also gives a com
hensive review of the patents appertaining to high-short sterilisat
With the exception of the processing of certain fruit juices and o
liquid packs where rapid heat penetration can be obtained the meth
suggested have not, as yet, been widely used.

Considerable attention has been directed to the processing
tomato juice and Cameron[31] describes a method in which the jui
pasteurised in continuous heat exchangers to temperat
substantially above its boiling point before filling the cans. The
are filled with the pasteurised juice at a temperature of not less t
195°F. and then inverted to sterilise the covers. After holding
one minute the cans are cooled in cold water.

In a recent patent[32] covering a method for the processing
evaporated milk, the milk is concentrated in the usual manner
then sterilised by subjecting the filled cans to temperatures in
280°-300°F. range at the same time as the cans are being rotate
speeds up to 200 r.p.m. In addition the oxygen in the headspa
replaced by an inert gas and it is claimed that milk processed in
manner does not develop an off-flavour.

The mechanism of the production of the characteristic flavou
evaporated milk has been studied by Tarassuk[33] who reached
conclusion that the colour and flavour could be improved by redu
the oxygen available in the headspace of the can before sterilisat

Studies of the behaviour of plant tissue when treated with solut
of calcium compounds lead Kertesz[34] to suggest that the firmnes
canned tomatoes could be improved by the addition of calc
chloride, and a method was developed by Kertesz, Tolman, Loco
and Ruyle[35] for treating tomatoes either before canning or by
introduction of a calculated quantity of a calcium salt to the
before sealing.

The treatment produces a firmer product which stands up
processing better than the untreated tomatoes. It has since b
shown by Loconti and Kertesz[36] and other workers that the act
is due to the formation of calcium pectate.

Recent work by Siegel[37] has shown that calcium sulphate produ
the same effect and the author describes the use of a tablet of calc
sulphate and common salt which performs the dual function
firming the tomatoes and of brining.

A somewhat similar development to the above took place dur
the war when large quantities of potatoes had to be packed for
Services. The normal procedure was to pack only during th

periods of the year when new potatoes were obtainable, as it had previously been found that potatoes taken from clamps or direct from the ground during the later part of the year tended to break-down during processing. The enormous requirements of the Services, however, could only be met if packing could be extended over a longer period, and experiments were, therefore, carried out to find a method of preventing the breakdown in texture. It was finaly found that treatment with calcium chloride produced the desired result, and Rhodes and Davies[38] demonstrated that provided the residual calcium chloride was kept below 0.2 per cent no foreign flavour could be detected and by combining the calcium chloride treatment with the careful selection of varieties of potatoes it was found possible to extent canning operations over a considerable portion of the year instead of the short period which was formerly the case.

The attractiveness of all types of food depends on a number of factors of which one of the most important is colour. It is, therefore, important that the natural colour of food should be retained during the canning process, and a recently developed method promises to achieve this result in the case of peas, spinach, asparagus, green beans, and the like.

The process which is the subject of numerous patents has been fully described by Blair and Ayres[39] and depends on the protection afforded to the natural chlorophyll of the vegetables when the pH value is raised by the addition of suitable alkalies in such a manner as to avoid spoiling the texture or the flavour of the product. High-short processing forms part of the technique and it is claimed that in addition to the colour the flavour is also improved.

A recent development to improve the washing of raw materials for canning especially peas is to use froth flotation methods similar to those used in the separation of minerals. The process is recommended as a supplement to existing methods and it is claimed that the process removes debris such as certain weed and flower seeds and broken peas and skins which are not removed by normal methods. The process of froth flotation depends on the fact that it is possible to attach air bubbles selectively to certain materials and thus change the apparent density so that instead of sinking when immersed in a given medium the material floats. The application of the process to the cleaning of peas has been fully described by Neubert and Veldhuis[40], the processing being divided into two operations, in the first, the peas are wetted with an oil-in-water emulsion and drained, while in the second, the peas are spread over the surface of a foam bath and the sinking and floating fractions separated, the floating fraction consisting of foreign matter while the sinking fraction consists of the peas which after washing are ready for canning. In a later article

Neubert[41] describes improvements of the process. A purified min[e]
oil is used as the internal phase of the emulsion and sodium la[u]
sulphate as the emulsifying agent.

Design of Equipment

During recent years increased attention has been directed to
design of cannery equipment to conform to the trend towards gre[at]
cleanliness in the cannery and a higher level of plant sanitation.

The removal of dirt and particles of food is facilitated by design[ing]
plant so that it can easily be dismantled and reassembled.

The use of wooden equipment of all kinds is now universa[lly]
condemned as it has been demonstrated that it frequently becor[nes]
infected with micro-organisms and, therefore, acts as a source [of]
contamination. Wherever possible stainless steel or Monel me[tal]
should be used.

Impact of Other Methods of Food Preservation

During recent years various new methods of food preservation ha[ve]
been developed and applied on a large scale. Dehydration, althou[gh]
not by any means a new method, has come to the fore as a means [of]
preserving all kinds of food including meat, milk, fish, vegetables a[nd]
fruit. With few exceptions, however, it is not likely to offer seri[ous]
competition to canning as in many cases the character of the food [is]
altered by the dehydration process. Exceptions are milk and pot[ato]
powder.

The quick freezing process has made great strides during the l[ast]
few years, particularly in the U.S.A. and there is little doubt that [in]
the future it will become a serious competitor in the canning indust[ry.]
The process suffers one serious disadvantage, however, in that it [is]
necessary to store all quick frozen foods in a refrigerator both at t[he]
producing factory and during distribution. Nevertheless there [is]
little doubt that quick freezing has come to stay, although it appe[ars]
likely that it will run hand in hand with canning and that there w[ill]
be a place for both processes. This is in fact the case in the U.S.[A.]
and many canners already produce frozen foods in addition to t[he]
canned product. In many cases the preparation procedure is t[he]
same both for canning and freezing and equipment is, therefo[re]
common to both processes.

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